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A Comprehensive Survey and Literature Review on TOPSIS

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ABSTRACT

Multi-criteria decision making is a complex process that involves considering various criteria or factors when making a decision. Over the past few decades, several researchers have developed different methods to tackle this problem. This method offers manifold advantages, however, it faces several limits leading to the development of different modified forms. This paper provides a comprehensive review on the TOPSIS concept to help the researchers gain an overview in different aspects of TOPSIS. The literature review presented in this paper offers a comprehensive survey of the TOPSIS method, providing researchers with an overview of the various aspects of the method, its strengths and limitations, and its various applications. The results of the literature review also are provided based on the application, methodology, and reasons to use TOPSIS method.

KEYWORDS

Multi-Criteria Decision Making (MCDM), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Method, Decision-making

INTRODUCTION

Multi-Criteria Decision Making (MCDM) strategies arise as crucial resources in the complex decision-making environment where multiple conflicting criteria need to be considered. These approaches enable decision-makers to evaluate and compare alternatives based on a variety of criteria, thereby providing a systematic method for addressing complex problems (Alamerew et al., 2020). The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), one of many MCDM techniques, has garnered much attention and praise for its straightforward methodology and adaptability.

Since its introduction in 1981 by Hwang and Yoon (Yoon & Hwang, 1981), TOPSIS has become a central concept in the disciplines of decision analysis and MCDM. At its core, TOPSIS provides a direct path to locating the optimal solution by ranking alternatives according to their distance from a positive ideal solution and proximity to the optimal response. TOPSIS is applicable in a variety of decision-making contexts and can incorporate both quantitative and qualitative criteria due to its unique methodology.

As the MCDM discipline evolves, TOPSIS has emerged as a crucial technique that intrigues both academics and practitioners. The fact that it can readily manage multiple types of data, such as linguistic, category, and numerical data, increases its appeal. Over time, researchers have enhanced

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TOPSIS by developing extensions, variants, and hybrid models that increase its efficacy and adaptability in a wide range of real-world decision-making scenarios (Divya et al., 2020; Goswami & Behera, 2021; Shih & Olson, 2022).

The applicability areas, benefits, and drawbacks of TOPSIS are elaborated upon in the following sections. The following sections detail the six primary and fundamental stages of this strategy, as well as the TOPSIS model. To gain a comprehensive understanding of the TOPSIS-based research efforts in the field of decision science, a comprehensive literature review of the TOPSIS-using articles is conducted. Included in the discussion section are the results.

THEORETICAL FOUNDATIONS OF TOPSIS

TOPSIS theoretical foundations provide decision-makers with a systematic method for evaluating and ranking alternatives based on several competing criteria. The premise underlying TOPSIS is that decision-makers must select from several options, each of which is defined by several characteristics. The objective is to identify the optimal option that meets all of these criteria (Shanian & Savadogo, 2006). In essence, TOPSIS seeks the solution that is the most distant from the positive and negative ideal solutions (Siregar, 2019).

These are the key concepts that support the functionality of TOPSIS. The optimal solution is a hypothetical point in the decision space where the criteria are maximized (benefit) or minimized (cost), and it represents the best outcome conceivable for each criterion. The gap between alternatives and this optimal solution measures performance. In contrast, the negative ideal solution yields the worst results for each criterion. In addition to the ideal solution, the distances from this negative ideal solution are computed. The core of TOPSIS is determining how near or similar each alternative is to these ideals, frequently employing distance metrics such as Euclidean and Manhattan distances. This method yields a preference function that incorporates normalized distances and weights to determine the final ranking of alternatives (Shih & Olson, 2022; Unutmaz Durmuşoğlu & Durmuşoğlu, 2021).

Multiple interconnected stages are involved in the mathematical formulation of TOPSIS. Normalization of the unprocessed data for each criterion is the first step in achieving comparability across multiple criteria. The resulting decision matrix takes normalized data into account and contains columns for normalized criteria and rows for alternatives. Finding the highest and lowest criterion values across all options produces ideal and unfavorable solutions. Using the selected similarity metric, such as Euclidean distance, the distance between each alternative and both ideal and negative ideal solutions is then calculated. Combining criterion weights and distances, the preference function facilitates aggregation and ranking. The outcome is a ranked list of options, with the most preferred option being the one that is nearest to the optimal solution and farthest from the unfavorable optimal solution (Shih, 2022b). Table 1 summarizes the sequential steps of the mathematical process underlying TOPSIS, including data normalization, decision matrix construction, ideal and negative ideal solution calculation, distance measurement, and aggregation for ranking alternatives based on criteria weights and distances.

TOPSIS stands out among the numerous MCDM approaches due to its straightforward geometric interpretation and usability. In contrast to more intricate algorithms, TOPSIS provides a technique that is straightforward to comprehend and employ. The optimal strategy will be determined by the decision maker's preferences and the specific characteristics of the decision problem. In conclusion, the guiding principles and mathematical framework of TOPSIS provide decision-makers with a powerful instrument for evaluating and ranking alternatives based on a variety of factors (Shih, 2022a).

LITERATURE REVIEW

The aim of this section is to provide a comprehensive and systematic literature review on TOPSIS method in the “Decision Science” subject area. For this purpose, the “TOPSIS” keyword is used

Table 1. Mathematical formulation steps of TOPSIS

Step	Description	Formula/Process
1	Normalize Criteria Data	Normalize raw data for each criterion and alternative (0 to 1 scale).
2	Construct Decision Matrix	Organize normalized data into a decision matrix.
3	Calculate Ideal and Negative Ideal	Ideal Solution: Max normalized value per criterion. Negative Ideal Solution: Min normalized value per criterion.
4	Calculate Distances	Use similarity measure (e.g., Euclidean) to find distances to Ideal and Negative Ideal.
5	Aggregate and Rank	Apply preference function with criterion weights. Rank based on distances: Shortest to Ideal and longest to Negative Ideal.

in the "ScienceDirect" database based on using "TOPSIS" as a search filter for the title, abstract, keywords, a filter for "decision science" for subject area, and without a time limit. The initial search had 301 results (conducted in 4/30/2022). But in the database, the publication titles with more than one papers are filtered and used in this study. The number of papers considering this aspetc was 274, and then all of the abstracts were analyzed and the selected papers (240 articles) are considered in this section. The process is shown in Figure 1. The final article chosen in this work are reviewed in four sub-sections. The sub-sections gather the papers based on the TOPSIS methodology used considering: traditional TOPSIS, modified/integrated TOPSIS (excluded TOPSIS/modified TOPSIS with fuzzy theories), fuzzy TOPSIS/TOPSIS integrated with different fuzzy theories and finally Integrated fuzzy TOPSIS with other methods. The results are discussed in each sub-section and they are summarized in Tables 2-5 to obtain a better overview.

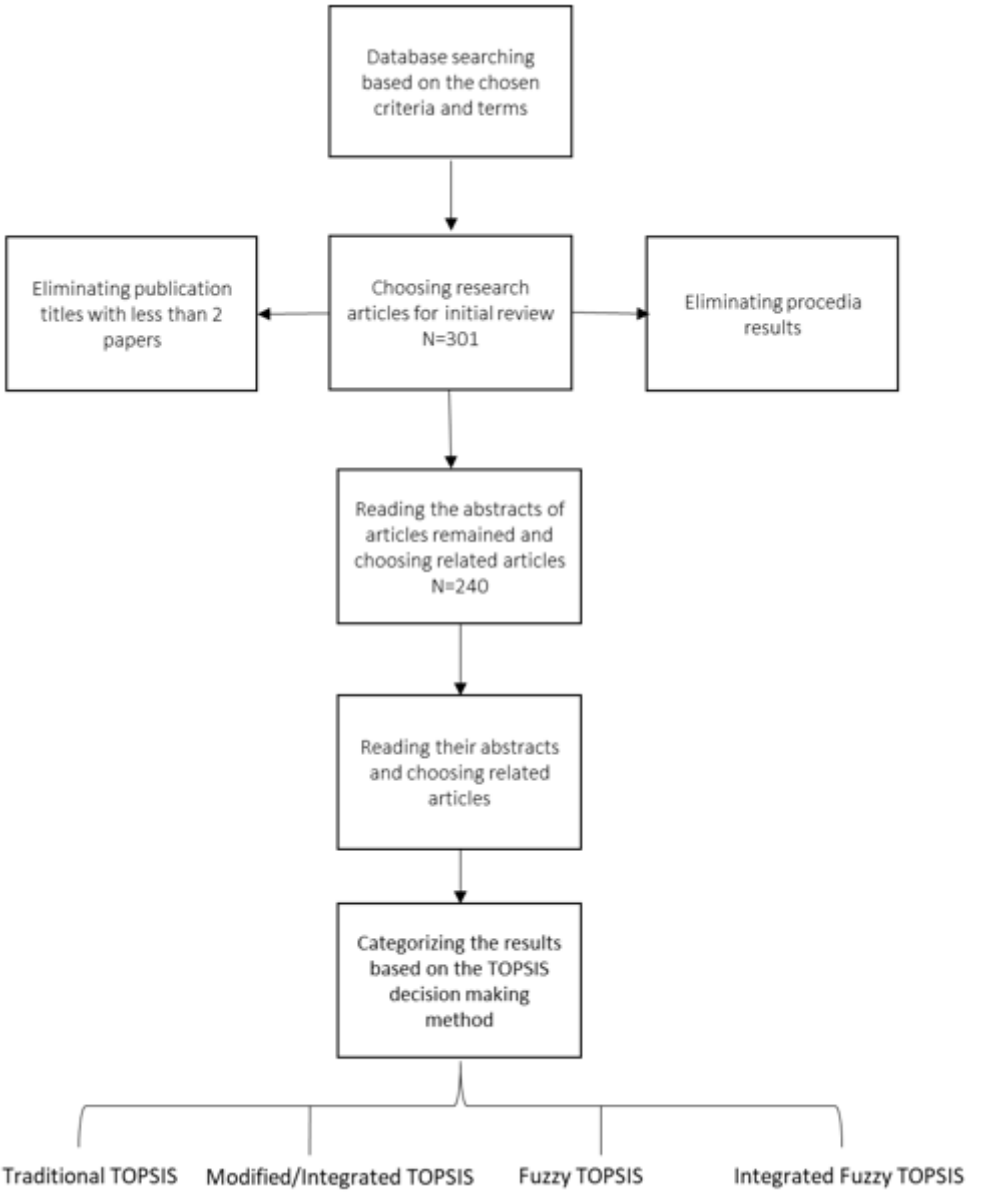
Traditional TOPSIS Method

In this sub-section, the papers using traditional and normal TOPSIS are reviewed based on the concept TOPSIS is used for decision making. For this purpose, the articles are categorized in different groups including industrial and manufacturing processes, supply chain, ranking models and methods, and comparing TOPSIS with other MCDM methods. Some articles can be mentioned in more than one category. But, the papers are categorized by using the above terms to gain a broad and comprehensive overview on the concepts focused in different works. For example, an article used in the "comparing TOPSIS with other methods" can focus on an industry case study, but the current category is used to show a comparison as well. Table 2 shows the articles based on the journals published them.

TOPSIS for Industries and Manufacturing Processes

The studies focused in this section used traditional TOPSIS for decision making in different industrial and manufacturing concepts such as allocating energy storage systems, biological processes, flow lines, powers systems, etc. In an MCDM problem, Karimi-Nasab and Seyedhoseini (Karimi-Nasab & Seyedhoseini, 2013) used TOPSIS to identify the best cutting plane. The alternatives are used to address the problem in two different approaches including branch-and-cut, and cut-and-branch. They used CPLEX 12.2 to investigate the performance of cutting planes, then they identified criteria and ranked them using TOPSIS. They took a shop floor in Iran that belongs to the defense ministry as an example. They used different performance indices to measure the performance of the cuts and ranked them using TOPSIS. A study by Chen et al.(Chen et al., 2017) presented a multi-objective mean–variance–skewness (MVS) model in order to assess the reliability of nonconvex and stochastic optimal power flow (NSOPF). They considered different parameters such as uncertain integrated wind power, stochastic load, and valve-point effect in this study. The aim of the study was to solve three objective problems related to minimizing risk, and maximizing skewness as well as expected return. Here, TOPSIS was utilized to identify the final dispatch solution. In this year, Ferjani et al.

Figure 1. Literature review process in this paper



(Ferjani et al., 2017) used TOPSIS to opt the machines that the workers should be assigned to them by considering different criteria. The focus of the study was to assign multi-skilled workers to the machines in a manufacturing system state. They aimed to reach the minimum mean flow-time value of jobs in the process. The system was considered dynamic, and the workers were assigned whenever they were available. In this problem, predicting the time of starting and completion was not possible. After that, Jani and Abdi (Jani & Abdi, 2018) in 2018 studied the optimal allocation of energy storage systems. They considered wind power uncertainty in their model, and aimed to minimize operation

costs, emissions, and voltage deviation in their study. Finally, they used TOPSIS for decision making problems related to finding the optimal solution considering the objectives.

Li et al. (Li et al., 2021) considered specific technologies, and measured the level/degree of emergence using a conceptual framework based on the theory of swarm intelligence. They used the basic TOPSIS in this study as a decision-making method to better visualize the results by evaluating and ranking on the emergence of the technologies.

Dong et al. (Dong et al., 2021) studied the methods of redesigning of a product. In this study, TOPSIS was utilized with the aim of evaluating and selecting five redesign solutions by considering different evaluation indexes. Siltori et al. (Siltori et al., 2021) used TOPSIS for decision making, Hierarchical Cluster Analysis, and Descriptive Statistics to investigate the effects of Industry 4.0 on corporate sustainability in a Brazilian setting. In this study, they used traditional TOPSIS for ordering 12 impacts such as physical and cognitive ergonomics, the emergence of innovative business, the reduction of job offers for manual and repetitive activities and the emergence of new high value-added professions, etc. identified by their descriptive analysis. In the transportation industry also TOPSIS can be used for rational decision making. Aktar et al. (Aktar et al., 2021) used TOPSIS in a problem related to the transportation system to rank the formulated models. They showed that apart from minimum cost, road's specific constants are other important factors that play an important role in the transportation models. They considered different objectives including cost, time, and CO_2 emissions. Finally, Rocco et al. (Rocco et al., 2021) applied TOPSIS method to choose a configuration between 12 different alternatives, as well as the buffer size in the manufacturing flow lines.

TOPSIS for DM in Supply Chain Area Using TOPSIS

The articles reviewed in this section have a main focus on stockholders, supplier selection, sustainable supply chain, etc. In these concepts, Safa et al. (Safa et al., 2014) investigated a supplier selection problem based on lead time, cost, preferred supplier and the performance criteria using TOPSIS method in industrial projects. In the same year, Validi et al. (Validi et al., 2014) considered the trade-offs between two factors including CO_2 emissions and total costs to gain a ranking based on TOPSIS method for transportation routes, and used the method for the sustainable supply chain in the food industry. They also compared three different GA-based optimizers in this study. In 2019, Hujainah et al. (Hujainah et al., 2019) studied the quantification and prioritization of stockholders by considering their influence. They used TOPSIS to evaluate and rank the stakeholders.

TOPSIS for Policies, Strategies, and Management Area

TOPSIS method also can be used to rank policies, strategies, and management concepts in different aspects such as environmental, managers' performances. Kim et al. (Kim et al., 1997) provided the integral view of an activity performance to help managers to determine the opportunities of activity investment. They used TOPSIS as the MCDM method, in their system, to gain the overall performance measure. So, they successfully generated a measurement method to compare an activity with the competitors in term of overall performance. Kao et al. (Kao et al., 2006) studied project portfolio scheduling and rescheduling MCDM problems. They used high level petri nets and activity-based costing frameworks for estimating the make span and costs, respectively. Then, they used TOPSIS to select the best schedule as the MCDM method.

A study by Khosroshahi et al. (Khosroshahi et al., 2021) used TOPSIS and considered different factors such as disclosure benefit policy, the cost of subsidy, and environmental policy to investigate the best government policy. Generally, four criteria were considered in this study including optimal objective values of the three policies along with Cs of each policy. Karimi et al. (Karimi et al., 2021) also determined the best strategy for the network microgrids. The strategy was best on obtaining the best scheduling ensuring the optimum cost for the system. By using a paired comparison matrix, the importance of objectives from an operator's viewpoint were determined. Then they used MADM

methods to investigate the importance of objectives by considering the perspective of operator. So, they ranked the operator's preferences using TOPSIS.

TOPSIS for Ranking Models and Algorithms

This method is also a suitable approach to rank methods and algorithms such as Genetic Algorithm. For this, Shahsavar et al. (Shahsavar et al., 2015) used TOPSIS to rank different Genetic Algorithms (GA). They used five different performance metrics according to the proposed literature work in this study. In a similar work Keramatpour et al. (Keramatpour et al., 2018) also compared different GA alternatives by considering four metrics and ranked the algorithms from the best to the worst according to the selected criteria. The method finally introduced the best algorithms for large and small size problems.

TOPSIS for Comparing TOPSIS with Other Methods

In this sub-section, the articles comparing the results of TOPSIS with other decision-making methods such as ELECTRE, VIKOR, AHP, etc. are reviewed. Li in 1987 (Li, 1987) formulated and solved a discrete decision making problem by using the concept of artificial intelligent. They coded different DM methods such as TOPSIS, ELECTRE, and a fuzzy based method in their study, and discussed the choice rules for the selected methods. For example, TOPSIS was used in the situation that the decision preference should consider the ideal solution's closeness. In this study different choice rules and methods rules were integrated into a logic-based decision support system directly. Zanakis et al. (Zanakis et al., 1998) compared different MADM methods, to investigate a criticism related to gaining different results by different methods. They analyzed the result of several techniques such as TOPSIS, SAW, ELECTRE, etc. They discussed that TOPSIS has more similar results to AHP, and the most differences with ELECTRE. Although they excluded the results for the problems with few criteria. In 2004, Opricovic and Tzeng (Opricovic & Tzeng, 2004) compared the results of two MCDM methods (TOPSIS and VIKOR) in a decision making problem. Although the results have similarities, some differences also were identified. For example, in VIKOR method normalized value does not depend on the evaluation unit in the related criterion, but in TOPSIS this factor can depend on this factor. In this year, Olson (Olson, 2004) compared different weighting schemes in TOPSIS process. Another study by Mulliner et al. (Mulliner et al., 2016) investigated and compared different MCDM methods including TOPSIS, revised AHP,CORPAS, the weighted sum model, and the weighted product model in a problem related to the assessment of the sustainable housing affordability. They used 20 criteria for 10 selected alternatives in a case study in England. They gained different results. For example, they found that although TOPSIS is more time consuming, and complex compared with CORPAS method in this problem, both methods could corporate benefit together with cost criteria simply.

In another study Liu et al. (Y. Liu et al., 2021) designed simulation experiments to investigate the ranking results of seven different MADM methods such as TOPSIS, PROMETHEE, ELECTRE, etc. In the average sense, TOPSIS gained the highest-ranking range, followed by ELECTRE method. It means TOPSIS can easier manipulate the ranking of alternatives and also it has the worst robustness among the methods. Mela et al. (Mela et al., 2012) studied an MCDM problem for the design of buildings. They used two, three, and four criteria for three different test problems. They compared the results of six MCDM methods such as PROMETHEE II, ELECTRE, and TOPSIS. However, they did not discover the best method in their study. Recently, Faghiri et al. (Faghiri et al., 2022) also studied an optimization problem related to acetone droplet impingement on phase change material based on maximizing the solid volume. The aim was to decrease the rate of phase change material melting and rising its freezing rate. They compared the results of two different decision-making methods including LINMAP, and TOPSIS to obtain the solidified paraffin area. Nicolalde et al. (Nicolalde et al., 2022) used an MCDM problem to find the best phase change material for vehicle's rooftop. They used VIKOR, COPRAS and TOPSIS as DM methods considering different weighting methods. For

this, Entropy weighting technique was compared with a new removal effect of criteria-based method. Finally, they compared the ranking obtained from three methods.

Modified and Integrated TOPSIS Method

This sub-section provides articles used modified and integrated TOPSIS methods excluding the fuzzy concepts and logics used to improve TOPSIS directly. In some articles other fuzzy decision methods (such as fuzzy AHP) are integrated with TOPSIS, but as the TOPSIS step is not fuzzy, these papers are also reviewed here. The concepts, and a short description showing the importance of method (where possible) are added in Table 3.

Modified/Integrated TOPSIS in Strategies and Management Concept

In this sub-section the focus is on the articles used modified/integrated TOPSIS method for ranking strategies and management concept. For example, in 2004, Tong et al. (Tong et al., 2004) investigated an optimization problem in a dynamic system which was based on Taguchi parameter design. The overall performance index in this study was based on the relative closeness to the ideal result of TOPSIS method. A case study was considered related to the biological reduction in an ethyl acetoacetate process. Yang et al. (Yang et al., 2007) compared the result of two decision making approaches (TOPSIS with AHP weighting and a fuzzy-based method) for a similar case study related to the strategies of allocation of operators in molding workstation. Kuo et al. (Kuo et al., 2008) investigated the dispatching problem in flow shop cases including multiple processors using an integrated method. AHP and TOPSIS MCDM methods were combined with Taguchi orthogonal array in this article. They considered a case study in a multi-layer ceramic capacitor (MLCC) manufacturing plant in their paper and selected the best dispatching rule/strategy for the workstations in that case. Both methods used HP for determining the weights. In this year also, Milani et al. (Milani et al., 2008) used a modified version of TOPSIS named 'block TOPSIS' with entropy weighting method to rank the different strategies for information technology projects. They applied their method in a service company and selected the best strategy with the proposed model and compared their results with a normal TOPSIS method.

Zandi and Tavana (Zandi & Tavana, 2011) used TOPSIS to find the best electronic customer relationship management (e-CRM) framework in the agile manufacturing. They first used different fuzzy models to prioritize the frameworks considering their financial properties and rank them by considering different perspectives including functional strategic, and operational agilities, and used the MCDM method in the final step to find the best alternative. Sheu (Sheu, 2010) in 2010, proposed a management model to address the relief demands of individuals who are affected by a large-scale disaster and face an emergency condition. They used a coupled method based on multi-source data fusion, TOPSIS, and fuzzy clustering in this study. TOPSIS was used to identify group-based relief demands urgency.

Wu et al. (Wu et al., 2010) used an integrated model based on TOPSIS and ANP to rank the marketing strategies. Different strategies such as differentiation strategy, cost leadership strategy, and segmentation strategy were ranked in this study using an easy to follow and understand method. Chen et al. (Chen et al., 2011) used a TOPSIS improved by a distance approach. This approach works based on extreme points, or predefined ideal and anti-ideal points. They compared the results of their study with traditional TOPSIS and VIKOR methods. As an example, they considered a case related to on-site manager recruiting. A study by García-Cascales and Lamata (García-Cascales & Lamata, 2012)suggested a modified context-dependent TOPSIS to address the rank reversal. For this, they introduced two fictitious alternatives. They modified the algorithms, so when two new alternatives are added to the problem, there would be need to resolve the problem for all of the alternatives again. Xu (Xu, 2013) in 2013 used a TOPSIS-based model in their study. The main focuses of the paper were firstly to minimize the divergences between the opinions of the group and the individual interval preference orderings, also to determine the experts' weights, and find the final rank directly using

Table 2. Articles including traditional TOPSIS

Journal	Reference	Concept
International Journal of Production Economics	(Rocco et al., 2021)	Assessing manufacturing flow lines
	(Khosroshahi et al., 2021)	Finding the best policy
	(Validi et al., 2014)	Assessing distribution system for sustainable food supply chain
	(Kim et al., 1997)	Recognizing opportunities for investment for manufacturing sector
European Journal of Operational Research	(Opricovic & Tzeng, 2004)	Comparing results of VIKOR and TOPSIS
	(Karimi-Nasab & Seyedhoseini, 2013)	Selecting cutting plane in a shop floor in defense ministry
	(Zanakis et al., 1998)	Selecting methods of MCDM between different methods such as ELECTRE, TOPSIS, AHP, etc.
	(Chen et al., 2017)	Assessing the optimal power flow in nonconvex and stochastic problem
Mathematical and Computer Modelling	(Olson, 2004)	Using different distance metrics and weighting schemes
Computers & Industrial Engineering	(Y. Liu et al., 2021)	Using different MCDM methods such as TOPSIS separately for decision making.
	(Ferjani et al., 2017)	Machine selection for assignment of workers
	(Aktar et al., 2021)	Transportation problems
	(Shahsavar et al., 2015)	Ranking different Genetic Algorithms for a project scheduling problem
	(Keramatpour et al., 2018)	Ranking different genetic algorithms
Technological Forecasting and Social Change	(Li et al., 2021)	Ranking processes related to the emerging technologies
	(Siltori et al., 2021)	Ordering the impacts of Industry 4.0 in Brazil using TOPSIS for decision making together with Hierarchical Cluster Analysis and Descriptive Statistics
Journal of Energy Storage	(Faghiri et al., 2022)	Comparing the results of TOPSIS and LINMAP for acetone droplet impingement concept
	(Nicolalde et al., 2022)	Selecting phase change material using different methods such as TOPSIS, VIKOR and CORPAS separately
	(Karimi et al., 2021)	Strategies for microgrids
	(Jani & Abdi, 2018)	Optimal allocation of energy storage systems
Decision Support Systems	(Hujainah et al., 2019)	Stockholder selection
	(Li, 1987)	Analyzing decision support systems comparing different methods such as TOPSIS and ELECTRE
Automation in Construction	(Safa et al., 2014)	Management of construction materials
Omega	(Mulliner et al., 2016)	Analyzing affordability of sustainable housing and comparing the results of different methods such as TOPSIS, revised AHP, CORPAS, etc.
Computers in Industry	(Kao et al., 2006)	Project Portfolio Management

continued on following page

Table 2. Continued

Journal	Reference	Concept
Advanced Engineering Informatics	(Dong et al., 2021)	Product development
	(Mela et al., 2012)	Building design

both the individual and collective interval preference orderings without any distortion and decision information losses. They used different case examples including alliance selecting partner for software company and the evaluating of key factors in cooperation of enterprises.

Jiang et al. (Jiang et al., 2015) developed a novel approach based on traditional TOPSIS. They used this approach to select the best computer development project. In the stochastic MADM problems the evaluation is based on the discrete stochastic variables of alternatives with respect to the considered attributes. In the study, they used a new metric to determine the distance between two discrete stochastic variables. Uygun et al. (Uygun et al., 2015) used an integrated approach based on fuzzy DEMATEL, fuzzy ANP, and TOPSIS to evaluate the SMEs (small and medium enterprises). TOPSIS method used to measure the level of institutionalization using different criteria such as process, strategic, human resources, and knowledge managements. Pätäri et al. (Pätäri et al., 2018) studied the quality of portfolio selection by using different methods. They combined different MCDM methods and compared the results. Their results, for example, showed that a TOPSIS-based combined method is a better choice for separating the future outperforming stocks from their underperforming counterparts compared with other proposed combinations.

Ocampo et al. (Ocampo et al., 2019) used different MCDM methods to evaluate the quality of services for government agencies. They integrated AHP, TOPSIS, and SERVQUAL model by considering the tangibility, reliability, responsiveness, assurance, empathy as main dimensions with different sub-dimensions. AHP is used to identify the most and least important dimensions that must be focused on their management and using TOPSIS in this problem to rank the dimensions based on the performance of government agencies in those dimensions. Zabihi et al. (Zabihi et al., 2019) studied a novel multi objective problem to determine the best allocation strategy based on skills, activities, workforces, and starting-time concepts. The objectives were to minimize the completion time and maximizing the efficiency using a hybrid AHP-TOPSIS approach. Also, Zhang et al. (B. Zhang et al., 2019) used a hybrid multi-objective optimization to minimize the total energy consumption and the makespan in a hybrid flow shop green scheduling problem (HFGSP). In this study, the TOPSIS method is used to help the algorithm to choose the promising solution.

Chalgham et al. (Chalgham et al., 2019) used different MCDM methods for ranking the inpatient departments in ward which was also tested in an specific hospital. This framework was proposed to help the hospitals to manage the patients when the pathology departments are crowded. They first used AHP based Delphi method for data collection, and then applied ELECTRE II, TOPSIS, and PROMETHEE to rank the departments. Micale et al. (R Micale et al., 2019) addressed a vehicle routing problem in a distribution company. They used the firefly optimization algorithm, and TOPSIS in their study. In this study, TOPSIS was used to rank the alternatives considering different criteria such as total distance, Carbon footprint, and Utilization coefficient. Tavana et al. (Tavana et al., 2021) used an integrated model based on best-worst method (BWM) and TOPSIS for ranking private partners for companies. BWM was used to identify the weights of different criteria (including economic, social, technological, and environmental main groups) and then TOPSIS was utilized in ranking step to identify the best partner with the best value. They also used the weighted influence non-linear gauge system (WINGS) method with aiming to analyze the intertwined criteria, and their relations. They used the suggested model in a specific initiative in a northeastern US city. Zhao et al. (Zhao et al., 2021) used an integrated an integrated method to gain scientific plans for a project in China considering the priorities related to environmental, ecological, social, and economic objectives.

They combined TOPSIS-based method and a pressure-state-response (PSR) method for evaluating and assessment. Then they used the results of the model in a goal programming-based model. They considered a water diversion project in China to assess their model by considering social benefits, ecological water shortage, environmental pollution, etc. as the objectives.

Turan et al. (Turan et al., 2021) considered three different objectives including workforce cost, capability gap, and capital and sustainment cost for the decision making problem. Their approach is a beneficial method for military decisions, and it is based on using a simulation-optimization method integrated with TOPSIS. They used Non-dominated Sorting Genetic Algorithm (NSGA) III and a System Dynamics (SD) simulation model for the simulation-optimization method, and TOPSIS for selecting the best Pareto front point. They used this model for the problems relating to the fleet renewal, asset management, and workforce planning for the navy sector in Australia. aIn 2021, Chen et al. (H. Chen et al., 2021) also studied a multi objective problem for selection of the investment portfolios. They integrated a Non-dominated Sorting Genetic Algorithm II (NSGA-II) with TOPSIS. In this study, the GA was used to define the set of Pareto for the optimal investment portfolios, and TOPSIS was utilized to detect the best solution considering the preferences of the investors. The method was used to select the overseas oil projects in China. Finally, Choudhary et al. (Choudhary et al., 2022) aimed to investigate the managing of returns in a circular economy considering a case for electronics industry in India to gain strategies related to remanufacturing and product recovery. They used a combined model based on combining the Interval 2-Tuple Linguistic (ITL) model and TOPSIS.

Modified/Integrated TOPSIS in Industry and Technology Fields

In this part, the articles in applied modified/integrated methods in different industries ranging from education and healthcare to aviation industry are listed. In manufacturing processes and product design different studies focused on this method. Gamberini et al. (Gamberini et al., 2006) studied a problem based on rebalancing new lines in industries using an integrated model. Their model used traditional TOPSIS for ordering the alternatives in the decision-making method step. Also, the well-known Kottas and Lau heuristic approach was applied in their algorithm. At each iteration, assignments are given as input data to TOPSIS and this method determines the best alternative. Ayağ & Özdemir (Ayağ & Özdemir, 2012) applied an integrated model worked based on TOPSIS and fuzzy ANP in their study. In this work, the relative weights were obtained based on ANP model, then a modified version of TOPSIS was used to rank machine tools based on their overall performances. They used different criteria such as flexibility, space, adoptability, precision, and reliability in the selection procedure.

Lin and Yeh (Lin & Yeh, 2012) aimed to maximize the network reliability together with minimize the cost that is possible using an optimal transmission line assignment. They used an integrated approach using a specific genetic algorithm (GA) and TOPSIS. GA searched the Pareto set, and then TOPSIS was used to rank the solutions. In a similar study, Taleizadeh et al. (Taleizadeh et al., 2009) used a hybrid method using Pareto, GA, and TOPSIS. They synthesized a solution range based on Pareto and GA. Then to select the best solution, they ranked them using TOPSIS. They used the hybrid model to conduct a case related to a multi-product inventory control problem to find the best option among eight products. Gallego-Ayala (Gallego-Ayala, 2012) applied a hybrid multi criteria method based on AHP and a modified version of TOPSIS for the selection of irrigation water pricing instruments. The suggested framework is useful for economic selection of the instruments. They considered economic, social, and environmental attributes in their model.

Wang et al. (Wang et al., 2021) used an Entropy-TOPSIS method to assess the level of development in manufacturing activities in China. They also considered lack of environmental assessment for carbon emissions in manufacturing development. Lin et al. (Lin et al., 2021)integrated Monte Carlo simulation (MCS) technique and TOPSIS for risk status evaluation in an excavation project. They used TOPSIS using a comprehensive method for determining the weights of the influential factors, and integrated it with MCM to overcome fuzziness, human errors, and uncertainty in the step of data collection. Zhang et al. (Zhang & Pan, 2021) investigated a new MCDM framework based on

the integration of Fuzzy AHP and TOPSIS for selecting the best tower crane layout in construction industries. They also validated their framework using a real-life modular integrated construction project. Lin et al. (M.-C. Lin et al., 2008) aimed to use an integrated method based on TOPSIS and AHP to help product designers to gain the best final solution considering their design objectives and customer requirements. Yang and Chou (Yang & Chou, 2005) addressed the multi-response simulation-optimization problems using a hybrid technique including TOPSIS and Taguchi methods to predict the system performances, and considered a case study related to an integrated-circuit packaging company to test their method. Mohanty et al. (Mohanty et al., 2018) used a novel method to select the best ergonomically designed product considering different attributes. They used TOPSIS, PROMETHEE, and VIKOR methods for this purpose. The case study of designing the best ergonomically chair for an office was investigated in this study as well.

Furthermore, Tavana et al (Tavana et al., 2015) used an integrated method based on fuzzy-AHP and TOPSIS for scheduling problems. They also used a goal programming (GP) approach in another step of their study to address the bi-objective problem that was gained as the result of two previous steps (fuzzy AHP and TOPSIS) in a manufacturing company. They investigated four repairmen as the alternatives for assigning to the machines considering reliability, time, cost criteria. Chang and Chen (Chang & Chen, 2010) used the combination of the fuzzy AHP and TOPSIS to assess the quality criteria in the solar silicon wafers to select the best slicing machine between three different lines. They used different criteria including parameter setting, multi-response, measurement, method checking, etc. Almomani et al. (Almomani et al., 2013) used an incorporated method for setup reduction problems. For this purpose, they used AHP, Preference Selection Index (PSI), and TOPSIS MCDM methods together with conventional setup reduction methods called Shingo's Single Minute Exchange of Dies (SMED). They examined their proposed method in a PVC industry to use the best setup technique. Shidpour et al. (Shidpour et al., 2013) integrated a multi-objective programming approach with TOPSIS in a product design optimization problem. They also used fuzzy AHP to find the relative importance of the criteria. These criteria were defined to evaluate suppliers of the components, assembly processes, the configurations of the design options. They used this method to investigate three new design alternatives in a mobile manufacturing considering four objectives (cost, satisfaction of customers, dependency risk, time to market) in the multi-objective programming, and used the quantitative and qualitative values as the result of this step in the TOPSIS method to find the final configuration, assembly process, and supplier.

In aviation industry, Ghorabaee et al. (Ghorabaee et al., 2017) evaluated five different airlines using a hybrid MCDM approach using 28 criteria. They used different MCDM methods including TOPSIS, EDAS COPRAS and WASPAS in their study. In the tourism industry, Kwok and Lau (Kwok & Lau, 2019) used a new decision support method called as Vague Set TOPSIS for a hotel selection problem as they found the assumptions and structure of traditional TOPSIS not suitable for their study. Kilic et al. (Kilic et al., 2014) used a three-step hybrid method for decision making. In this method, they used fuzzy AHP for weighting the criteria, and TOPSIS to rank the alternatives in a problem related to the ERP selection at airlines in Turkey. Feng and Wang (Feng & Wang, 2000) used TOPSIS to rank airlines by considering the financial ratios. They redeveloped a conceptual framework based on financial and transportation factors. They used the grey relation analysis to find the representative indicators, and then rank them based on TOPSIS method. They conducted a case study by considering Taiwan's major airlines using the suggested framework and methods. Barros and Wanke (Barros & Wanke, 2015) used TOPSIS to investigate the relative efficiency of the African airlines. They combined neural networks with TOPSIS results to get a model with effective predictive ability. They introduced the network size-related variables as the most important variables for determining the efficiency level. In a similar study, Wanke et al. (Wanke et al., 2015) investigated the performance of Asian airlines using TOPSIS method. They used this method to rank the efficiency levels of 35 airlines by considering different criteria. Then, they combined the results of TOPSIS

with Markov Chain Monte Carlo Generalized Linear Mixed Models (GLMM-MCMC) methods to gain a predictive analysis.

In financial and banking sector, Ouenniche et al. (Ouenniche et al., 2018) investigated a modified TOPSIS method in bankruptcy prediction. For TOPSIS classifiers an integrated in-sample and out-of-sample framework was proposed in this method. Li and Lai (Li & Lai, 2014) used an integrated method for supporting online users in purchasing based on a social appraisal mechanism (SAM). This mechanism incorporates the social network analysis (SNA) techniques, intuitionistic fuzzy sets (IFSs), and TOPSIS. The IFS was used to address the problems related to the information incompleteness, and the TOPSIS method, in the final step, was used to rank the final options.

In the education industry also different papers used TOPSIS based methods. Li et al.(Li et al., 2015) in 2015 proposed a for context-free grammar judgment for evaluating the individual research output for education industry area. They first structured a decision hierarchy, then used a distance-based method for calculating the weights, and finally used a TOPSIS-based technique for aggregate all rating considering both subjective and objective criteria. de Farias Aires and Ferreira (de Farias Aires & Ferreira, 2019) proposed R-TOPSIS as a new MCDM method. This method adds promising advantages to normal TOPSIS as it can address rank reversal, and there are no need additional learning requirements, although in this method decision makers should define an additional input parameter to the model, and criteria domains must be identified.

Thong et al. (Thong et al., 2019) proposed a new TOPSIS approach based on "Dynamic Interval-valued Neutrosophic Set (DIVNS)" theory, and applied it for evaluating the performance of lecturers in a university in Vietnam. In the concept of the productivity of research in cloud security, Garg et al. (Garg et al., 2019) ranked effective journals considering different parameters using an improved version of TOPSIS with AHP. In the education industry also some authors used modified and integrated TOPSIS based methods. Conejero et al. (Conejero et al., 2021) used MCDM methods for education industry in Spain. They used TOPSIS together with a novel decision support technique used to evaluate the impact of the criteria based on the analysis of the worst-best case scenario.

In transportation industry, Marchetti et al. (Marchetti & Wanke, 2020) used a novel hybrid method based on TOPSIS and GA for evaluating the performance of Brazilian Rail Cargo Systems. In a similar concept, Wei and Lee (Wei & Lee, 2021), studied a hybrid method used an improved TOPSIS for selecting the main inland ports for China Railway Express. In another study, Li et al. (Li et al., 2018) used an improved entropy TOPSIS to rank the imported grain distribution centers considering different factors. In this work, they selected the nodes with a qualitative method, then applied complex network theory to investigate the nodes' importance. Huang et al. (Huang et al., 2018) also used a new method based on Entropy-TOPSIS for evaluating the urban rail transit systems considering several indicators and sub-indicators. They tested their new approach using Chengdu subway system case study in China. In addition, Sobhani et al. (Sobhani et al., 2020) used an AHP-TOPSIS together with PESTLE qualitative method to evaluate and rank Unconventional modes (UCM) of transport in Dhaka, Bangladesh. In this industry, Chen et al. (Chen et al., 2014) also integrated Multilevel grey evaluation (MGE) and TOPSIS methods and also integrated the subjective and objective weights for evaluating transfer performance of transportation terminals using a railway station case study in China. They considered different criteria such as sustainable development and transfer efficiency in this work. Another study also was performed by de Lima Silva and de Almeida Filho (de Lima Silva & de Almeida Filho, 2020) that proposed new versions of TOPSIS to overcome the rank reversal issue in traditional TOPSIS. They used the proposed models in a case related to economic freedom degree in 180 different countries. They called one of the proposed models TOPSIS-Sort-B to address sorting problems that needs to determine the boundary profiles. TOPSIS-Sort-C also was presented to use in the problems that determining characteristic profiles is preferred. Kandakoglu et al. (Kandakoglu et al., 2009) in a DM for a shipping registry problem used AHP method together with TOPSIS to obtain the best open registries when taking the advantages of SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis to identify the key factors in this assessment. They

used AHP to calculate the relative importance of the criteria, and TOPSIS to rank the alternatives. In this study, different criteria were chosen, and the results showed that the reputation of registered ship owners was the most important criterion.

In manifold technology fields, researchers also used TOPSIS for decision making in the technology fields such as robot selection, water treatment technology selection, storage technologies, etc. Parkan and Wu (Parkan & Wu, 1999) used various quantitative methods for a robot selection problem. They used and then compared different MCDM methods. Finally, they combined the results of OCRA, TOPSIS, and a utility model to gain the results by using an averaging technique for the ranks obtained from three methods. In this concept, also Shih (Shih, 2008) investigated the importance of incremental analysis in MCDM problems in their study. This study developed a procedure with 11 steps by applying incremental analysis for TOPSIS in group decision making. An example of robot selection was presented to show the applicability of the modified TOPSIS method. Işıklar and Büyüközkan (Işıklar & Büyüközkan, 2007) applied an MCDM method using AHP and TOPSIS to rank the alternatives for mobile phones considering different criteria. Wang and Shih (Wang & Shih, 2013) incorporated DEMATEL and TOPSIS for the product development process considering the preferences of customers. They used a hybrid framework that integrates quality function deployment (QFD) and conjoint analysis (CA) to consider the preferences of the customer together with product development process and applied their suggested framework for the assessment of ultra books prototypes. Sianaki al.(Sianaki et al., 2018) used TOPSIS for ranking the equipment based on the criteria that were assigned using Delphi method to help energy managers. They used the proposed model in a metal component manufacturing factory. Jalayer et al. (Jalayer et al., 2018) used a hybrid model based on multi attribute and community-based approaches for the purpose of influence maximization in social networks. As the MADM method, they used traditional TOPSIS and they called their approach as 'Greedy TOPSIS and Community-Based' (GTaCB) algorithm. They investigated their method using various real-word networks and the spread of the selected seeds' effect was tested on them. Ren et al. (Ren et al., 2017) used a generic MCDM method for urban sewage sludge treatment technologies. They utilized different decision methods including BWM, sum weighted method (SWM), digraph model, and TOPSIS considering different social, environmental, technological, and economic criteria. Their studied three technology known as drying incineration, composting, and landfilling in their article and ranked them to find the best sustainable technology using the decision support framework for a case study in a city in the south of China.

In storage technologies, Li et al. (de Lima Silva & de Almeida Filho, 2020) investigated the optimal design of a thermal storage system using a single objective optimization problem by satisfying the unilateral requirement. They used different methods and algorithms to model the system. Finally, for decision making step, they identified the final optimal solutions by comparing the results of LINMAP and TOPSIS. Sohani et al. (Sohani et al., 2022) worked on a decision making problem to find the best phase change material thickness for a storage technology in building integrated photovoltaic thermal systems using the combination of TOPSIS and NSGA-II techniques in a multi objective optimization problem. Shi and Asgari (Shi & Asgari, 2022) also analyzed the energy, exergy, and economics of a novel integrated thermal storage system with thermodynamic cycles. In this system, the optimal output data were collected as a Pareto frontier. The multi objective problem was based on the multi-objective particle swarm optimization (MOPSO) algorithm, and by considering the comparison of the results of two DM methods (TOPSIS and LINMAP) the final optimum points were calculated. Anilkumar et al. (Anilkumar et al., 2021) investigate the optimum phase change material for an integrated solar box cooker with thermal storage system. They used different MCDM methods such as EDAS, MOORA, and TOPSIS using the weights found by Entropy, AHP and CRITIC techniques, and finally compared the rankings from the MCDM methods to find the best option. Maleki et al. (Maleki et al., 2021)) studied a thermal energy system using phase change materials. The aim of this study was to minimize the time of the phase change process and maximize the stored energy. In this study, they used a hybrid method using different approaches such as NSGA-II and MCDM methods. They applied TOPSIS

and VIKOR methods were used to find the best design points based on the objectives and different weights. Their results showed that in this study (under specific conditions) TOPSIS had better results compared with VIKOR. Zaidan et al. (Zaidan et al., 2015) used five different AHP-based integrated methods including AHP integrated with TOPSIS, WSM, WPM, HAW, and SAW. They aimed to evaluate their study using various metrics such as developer support, user support, and security, and compared the results of the methods for software selection.

Modified/Integrated TOPSIS for Ranking Locations, Cities etc.

TOPSIS also is one of the widely used methods for ranking in this concept. there are different methods to enhance TOPSIS including modified, hybrid and integrated methods reviewed following:

Jahanshahloo et al. (Jahanshahloo et al., 2009) used an extended TOPSIS with interval data to overcome the difficulties related to identifying the elements' exact values in the DM matrix. For this they added values as intervals. They used an example for choosing the best place between six cities in Iran for a data factory to test their method. Jahanshahloo et al. (Jahanshahloo et al., 2011) in another similar study in 2011, presented a cross-efficiency model for ranking units with an extended TOPSIS approach. They used TOPSIS based on an interval case. They used the suggested algorithm to rank six cities to find the best option for locating a data factory. They used different criteria such as distance from the border, costs, and product in region. Bilbao-Terol et al. (Bilbao-Terol et al., 2014) proposed different additive -TOPSIS versions for ranking different countries based on evaluating the sustainability performance of the government bond funds. They used different sustainability indexes such as Human Development Index and environmental performance in their study. Özceylan et al. (Özceylan, Çetinkaya, et al., 2016) ranked 81 provinces of Turkey using AHP, ANP, and TOPSIS by considering 16 different economic and geographic factors. Özceylan et al. (Özceylan, Erbaş, et al., 2016) presented a (GIS)-based MCDM method to investigate the best locations for freight villages. As MCDM methods, they used ANP method for weighting the criteria, and TOPSIS to rank the alternatives and selecting the best one. They tested this approach using a case study in Ankara, Turkey. They used different criteria such as cost and slope of land, proximity to highway and railway systems.

Kuo (Kuo, 2017) proposed a new ranking index for TOPSIS that this index is superior to the original one as the original one is reasonable but contains a flaw. They used this method to rank location of Asian seaports. They concluded that affordable industrial land with accessibility to the main roads as well as good receivers are the most important factors. They considered a vast range of criteria including five main groups with 34 sub-criteria in the study. N-DEMATEL was used to reveal the importance of factor, and then TOPSIS was applied for evaluating and ranking the alternatives. They took an example for district municipalities of Istanbul, Turkey to rank 39 alternatives. Carayannis et al. (Carayannis et al., 2018) used a combined MCDM method based on AHP and TOPSIS to gain the criteria weights and determine the national and regional Innovation Scoreboards rankings considering four Quadruple Innovation Helix (QIH) actors. Micale et al. (Rosa Micale et al., 2019) used an integrated MCDM method based on ELECTRE TRI and TOPSIS for assigning the products to the levels of shelf and determining the locations of storage; respectively in the logistic services of a Sicilian company in Italia. They used different criteria for instance demand, profitability, space, and popularity in their study. Ahmad et al. (Ahmad et al., 2020) used a new hybrid probabilistic optimization algorithm to gain the optimal allocation of energy storage systems with similar objectives (based on minimizing cost, emissions, and voltage deviation). They used TOPSIS in their algorithm before the end of each iteration to gain the best/optimal solution.

In 2019, Akgün and Erdal (Akgün & Erdal, 2019) also considered an MCDM problem to investigate the allocations and locations of depots in order to minimize the cost of transportation as well as average risk levels. They used a combined model based on AHP and TOPSIS to gain the weights and risk scores; respectively. They also used a GIS analysis to gain the location of depots. Zhao and Ke (Zhao & Ke, 2017) studied an optimization model aiming to minimize total cost and risk factors for a problem related to the location and routing decisions. They used a modified TOPSIS method

in decision making step. In another work, Özceylan et al. (Özceylan, Erbaş, et al., 2016) presented a (GIS)-based MCDM method to investigate the best locations for freight villages. As MCDM methods, they used ANP method for weighting the criteria, and TOPSIS to rank the alternatives and selecting the best one. They tested this approach using a case study in Ankara, Turkey. They used different criteria such as cost and slope of land, proximity to highway and railway systems.

Aljohani and Thompson (Aljohani & Thompson, 2020) aimed to investigate suitable locations for consolidation facility using an integrated decision framework. They considered different aspects related to operational requirements, societal-related concerns, and spatial factors. They ranked 20 alternatives for the sites using TOPSIS. Liu et al. (E.-n. Liu et al., 2021) used an Improved version of TOPSIS, to study the transformation levels of resource-based cities in China. They considered different categories for cities (such as green cities, oil-based cities) based on their regions, development stages, and their dominant resources, and ranked them based on transformation effects. In another study, Kilic and Yalcin (Kilic & Yalcin, 2021) integrated two methods including Neutrosophic DEMATEL (N-DEMATEL), and TOPSIS to compare the performance of municipalities in terms of performance evaluation and environmental sustainability. Kapoor et al.(Kapoor et al., 2021) used an integrated MCDM method using AHP and TOPSIS to select the best smart and sustainable village considering different dimensions. Montanari et al. (Montanari et al., 2021) proposed an allocation method, and compared it with normal techniques using a numerical example for ranking 280 storage locations for a warehouse setting problem. The method is called Interval-Value TOPSIS (IV-T). Finally, Gul and Yucesan (Gul & Yucesan, 2022) developed a model for university ranking for higher education industry. They used a Bayesian Best-Worst Method (BBWM) for weighting step and then ranked the alternatives that were 189 public and private universities in Turkey.

Modified/Integrated TOPSIS for Decision Making in Supply Chain

Insupply chain area, the integrated andmodified TOPSIS are also used by many authors. Shyur and Shih (Shyur & Shih, 2006) used a hybrid process with five steps based on integrating ANP method for gaining the relative weights, and TOPSIS in their study. They used TOPSIS in this hybrid system to rank the alternatives based on overall performance. Seven different criteria (such as quality of the product, responsiveness to customer needs, and on-time delivery) were applied in an example of vendor selection for a company in Taiwan. in 2008, Lin and Chang (Lin & Chang, 2008) investigated decision making problem related to the selection of the orders and suppliers' pricing process using mixed integer programming (MIP) models and TOPSIS method. They also used a fuzzy approach to evaluate the buyers in the first section of this study.

Yang et al. (Yang et al., 2011) evaluated the supply chain process in term of robustness for different strategies such as e-Shopping, traditional, and emergency transshipments. They used a hybrid method based on Taguchi method and different MCDM methods including SMART, TOPSIS, and GRA. In this model, they used MCDM methods to evaluate the overall performance of the selected supply chain strategies based on different criteria, and their results showed similar ranking for alternatives. Validi et al. (Validi et al., 2014) considered the trade-offs between two factors including CO_2 emissions and total costs to gain a ranking based on TOPSIS method for transportation routes, and used the method for the sustainable supply chain in the food industry. They also compared the results of three different GA-based optimizers in this study.

Furthermore, Maghsoudlou et al. (Maghsoudlou et al., 2016) in a specific supply chain problem used a hybrid method based on TOPSIS and AHP to rank different parameter-tuned algorithms and find the best alternative considering different metrics as the criteria. Miranda-Ackerman et al. (Miranda-Ackerman et al., 2017) used an integrated model based on lifecycle assessment, GA, and TOPSIS for supply chain field. They used an orange juice supply chain case to test and validate their model. Sureeyatanapas et al. (Sureeyatanapas et al., 2018) used a TOSIS-based method to select the best supplier, and applied the rank order centroid technique for determining the criteria weights. An egg supplier selection was investigated as the case study in this work. Dev et al. (Dev et al., 2019)

studied a hybrid method based on TOPSIS and fuzzy ANP for a supply chain as well. In these kinds of problems with the combination of fuzzy and normal approaches, the fuzzy values must be turned into a de-fuzzified definitive number using different suggested formula such as Minkowski that was used in this study. Darestani and Hemmati (Darestani & Hemmati, 2019) designed a supply chain network, and used TOPSIS to rank their suggested models. They considered the uncertainties related to the corruption of perishable goods in the supply chain. The objective functions in this study were minimizing the total cost of the network, and greenhouse gas emissions. They also considered the uncertain parameters such as demand, goods transportation and operational costs, etc. They used different objective models to solve the optimization problem. In the last step, TOPSIS was used to find the most efficient model using specific indices including first and second objective function value, and computational time.

Mohammed et al. (Mohammed et al., 2021) used a hybrid method based on integration of MADM and possibilistic bi-objective programming model (PBOPM). The objective of the MADM problem was to minimize the costs and maximize the value of resilient sourcing. As the MADM approach they used a DEMATEL-TOPSIS method using 10 different sets for the criteria weights of the decision problem. They developed the PBOPM based on the incorporated results of the DEMATEL-TOPSIS. TOPSIS was used for scoring the performance of suppliers, and DEMATEL for determining the relative criteria weight. The result of this method was compared with other MADM methods including OCRA, VIKOR, etc.

Kaur and Singh (Kaur & Singh, 2021) prioritized and ranked suppliers in their study by integrating fuzzy AHP and TOPSIS methods. They also computed the risk related to each supplier and proposed a Mixed Integer Program (MIP) as an optimization method with the aim of minimizing risk and overall costs. Khoshsirat et al. (Khoshsirat et al., 2021) proposed a supply chain model based on three phases including "announcement, construction, and evaluation". They used a fuzzy PROMETHEE for ranking the suppliers in the evaluation phase and solved the multi-objective model using an augmented ϵ-constraint method. In this model, each supplier offered just one bid, and TOPSIS was used to rank the Pareto solutions, obtained by the construction model and gain the best bid.

Deepu and Ravi (Deepu & Ravi, 2021) integrated AHP and TOPSIS to select the best Inter-Organizational Information Systems option in an electronic supply chain. AHP and TOPSIS were used to determine the criteria weights and rank the alternatives, respectively. In this year, also Chen et al. (C. chen et al., 2021) investigated a multiperiod anticipatory shipping problem. The objective of this problem was to minimize the online retailers' cost and maximize the customers' saved waiting time. They used different machine learning algorithms in this study, and the final step was to find the final optimal solution from the Pareto set obtained by one of the algorithms (NSGA-II) using different decision-making methods including TOPSIS, LINMAP, and Shannon entropy, and compare their results.

Modified/Integrated TOPSIS for Ranking Methods and Algorithms

This method can also be used to rank methods and different algorithms as for example, Peng et al. (Peng et al., 2011) aimed to develop a fusion approach named (FMCDM) and apply four MCDM methods including TOPSIS, WSM, PROMETHEE, and VIKOR for ranking multiclass classification algorithms. The fusion approach can address the conflicting rankings generated by four decision making methods, and it helped to gain secondary rankings for the MCDM methods that were in strong agreement.

Fuzzy TOPSIS/ TOPSIS Integrated with Different Fuzzy Theories

TOPSIS method also can be used in different fuzzy forms. For these different methods can be applied. For example, fuzzy logic and fuzzy set theory can be applied together with TOPSIS mainly to address uncertainty in the problems. These methods are used in manifold concepts reviewed following. The articles also are summarized in Table. 4.

Table 3. Articles focusing on modified/integrated TOPSIS based methods

Journal	Reference	Description	Method	Concept
International Journal of Production Economics	(Wu et al., 2010)	Adding the advantages of ANP method to the rational logic and straightforward process of TOPSIS.	ANP and TOPSIS	Marketing strategies
	(Ayağ & Özdemir, 2012)	Using integrated method to address the time-consuming fuzzy calculations of the fuzzy ANP method.	Modified TOPSIS and alpha-cut based fuzzy ANP.	Machine tools
	(Choudhary et al., 2022)	Addressing issues related to uncertainty and incomplete information in decision-making.	Combined ITL and TOPSIS	Managing remanufacturing and product recovery projects
	(Kaur & Singh, 2021)	Applying TOPSIS as a less complicated and easy-to-understand method together with advantages of AHP method in a fuzzy environment.	FAHP-TOPSIS Note: TOPSIS step is not fuzzy	Assessing and prioritizing suppliers
	(Gamberini et al., 2006)	Applying TOPSIS due to its applicability in a wide variety of fields, and integrating it with heuristic approaches as effective methods to solve problems related to assembly lines.	TOPSIS and Kottas and Lau heuristic approach	re-balancing an existing line problem
	(Yang et al., 2011)	-	Hybrid method based on Taguchi method with different MCDM methods including TOPSIS, GRA, and SMART	Evaluation of robustness of supply chain information-sharing strategies
	(Zhao & Ke, 2017)	Solving bi-objective optimization within a reasonable time by turning them into a single objective model.	Modified TOPSIS	Waste Management
	(Shih, 2008)	Using a modified TOPSIS for its ease of use and stability with cardinal information.	Modified TOPSIS	Example of robot selection
	(Wanke et al., 2015)	Gaining better apprehended compared to other two-stage approaches, and benefitting the advantages of TOPSIS together with GLMM-MCMC as a powerful method for trade-off balancing between interpretability and accuracy that can offer estimates for the standard deviations of multivariate random variable support and means.	Combining the results of TOPSIS with GLMM-MCMC	Efficiency of Asian airlines

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Table 3. Continued

Journal	Reference	Description	Method	Concept
European Journal of Operational Research	(Kuo, 2017)	Proposing a new ranking index because it is intelligible and superior to the original one.	modified TOPSIS with a different ranking index	Ranking location of Asian seaports.
	(Lin & Yeh, 2012)	Using NSGA-II to obtain Pareto sets with TOPSIS to gain the best compromise solution considering each criterion as independent together with NSGA-II to determine the Pareto set.	NSGA-II and TOPSIS	Stochastic computer networks
	(Pätäri et al., 2018)	Comparison of methods for portfolio selection	TOPSIS-based, AHP, and DEA	Portfolio selection
	(Lin & Chang, 2008)	Dealing more objectively with the pricing process and order selection more objectively.	TOPSIS used with MIP	Selecting order and pricing process in supply chain
	(Tong et al., 2004)	-	Identifying overall performance index for multiple responses using TOPSIS and Taguchi parameter design	-
Mathematical and Computer Modelling	(García-Cascales & Lamata, 2012)	Addressing Rank reversal phenomenon and offering a context dependent method.	Modified TOPSIS	Different examples such as assessing candidates to occupy a certain position
	(Jahanshahloo et al., 2009)	Addressing the difficulties for determining the exact value of some elements of decision matrix by considering the values as intervals.	Extension of TOPSIS with interval data	Example: finding the best place for creating a date factory in six different cities in Iran
	(Jahanshahloo et al., 2011)	Overcoming the problem related to the gaining not unique optimal weights using a modified cross-efficiency method.	Extension of TOPSIS with interval case	Example: finding the best place for creating a date factory in six different cities in Iran
	(Taleizadeh et al., 2009)	Using a modified TOPSIS due to its comprehensible and rational concept and its simplicity in computation processes.	Hybrid method using Genetic Algorithm, Pareto, and modified TOPSIS	Inventory control systems

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Chen et al., 2011)	Improving TOPSIS using a distance approach based on extreme points that can offer different merits including Interpreting extreme points more clearly, flexible to set extreme points, eliminating normalization distortion, and handling non-monotonic criteria.	Improved TOPSIS	Example: recruiting an on-site manager
	(Shyur & Shih, 2006)	Being suitable for ranking competing vendors due to their overall performance considering multiple interdependence	Hybrid method based on ANP and modified TOPSIS techniques	strategic vendor selection
	(Kandakoglu et al., 2009)	Proposing a relatively simple and an appropriate decision-making tool for strategic DM problems by taking the advantages of SWOT.	multi-methodological approach: SWOT analysis, the AHP and the TOPSIS	Shipping registry selection in maritime transportation industry
	(Gallego-Ayala, 2012)	Using a modified TOPSIS with better interpretation using weighted Euclidean distances instead of the n-dimensional Euclidean distance.	AHP and modified TOPSIS	Selecting irrigation water pricing alternatives
	(Milani et al., 2008)	Finding TOPSIS based methods as efficient tools in these concepts.	Comparing TOPSIS and a modified TOPSIS	Analyzing human behavioral resistance in strategic DM problems
Socio-Economic Planning Sciences	(Gul & Yucesan, 2022)	Addressing the issues related to the loss of information applying BBWM while dealing with group DM problems.	an integrated Bayesian BWM-TOPSIS model	Performance evaluation of Turkish Universities
	(E.-n. Liu et al., 2021)	Using a modified method to address the limits of traditional method due to getting the impacts of each object and obtaining from the evaluation system existing.	An integrated sequential weight and TOPSIS approach	Assessing the transformation resource-based cities in China
	(Kilic & Yalcin, 2021)	Addressing the indeterminacy and inherent ambiguity of DM process together with revealing the significant of factors' while consider the interaction between them, and then ranking them using the method.	Neutrosophic DEMATEL based TOPSIS	Ranking municipalities

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Ocampo et al., 2019)	Using AHP-TOPSIS to identify input critical dimensions of the SERVQUAL model.	SERVQUAL and AHP-TOPSIS	Public service quality evaluation for Philippine government agencies
	(Tavana et al., 2021)	-	composed of BWM, WINGS, and TOPSIS.	Selecting private sustainable partner
	(Zhao et al., 2021)	-	comprising a qualitative PSR based TOPSIS evaluation method and a quantitative MOP mode	Water resources diversion and allocation
	(Wang et al., 2021)	Reducing the interference considered to be subjective using entropy method and gaining more accurate and reasonable results.	Entropy TOPSIS	Assessing development level of manufacturing activities
Computers & Industrial Engineering	(Montanari et al., 2021)	Grounding on membership intervals IV-T approach.	Interval-Value TOPSIS (IV-T)	Allocation strategies
	(Parkan & Wu, 1999)	-	Averaging the results of OCRA, TOPSIS, and a utility model.	Robot selection
	(de Lima Silva & de Almeida Filho, 2020)	Using TOPSIS-Sort-B for sorting problems that need determining boundary profiles. Determining problems related to characteristic profiles using TOPSIS-Sort-C.	New versions of TOPSIS	Example: assessing the degree of economic freedom of 180 countries
	(de Farias Aires & Ferreira, 2019)	Avoiding rank reversal and not requiring learning related to the traditional method.	R-TOPSIS	Selecting engineering students
	(Rosa Micale et al., 2019)	Dealing with uncertain and incomplete input data.	A combined interval valued ELECTRE TRI and TOPSIS approach	solving the storage location assignment problem
	(Akgün & Erdal, 2019)	Dealing with large-scale, original, and real-world problems.	Combined AHP-TOPSIS, and GIS	Solving an ammunition distribution network design problem
	(Mohammed et al., 2021)	Addressing the need for more integrated methodologies towards resilient SC.	Hybrid DEMATEL-TOPSIS-possibilistic approach	Quantifying the resilience of existing suppliers and assessing its performance

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Turan et al., 2021)	-	Integration of a simulation–optimization method with TOPSIS	Case studies: military workforce planning, asset and fleet management
	(H. Chen et al., 2021)	Gaining better results for complex real-world problems	Integration of NSGA-II with TOPSIS	Selecting overseas oil projects
	(Tavana et al., 2015)	Using TOPSIS to turn the multi-objective problem into a bi-objective problem.	Fuzzy AHP together with goal programming and TOPSIS	Maintenance scheduling.
	(Chang & Chen, 2010)	Combining the merits of methods for gaining better results.	Integration of Fuzzy AHP and TOPSIS	Solar silicon wafer machine line
	(Jiang et al., 2015)	Overcoming the limitations of TOPSIS for example information loss during transforming stochastic attribute values.	A novel TOPSIS-based method	Different examples such as: select the most desirable computer development project(s
	(Uygun et al., 2015)	-	Integration of Fuzzy DEMATEL, fuzzy ANP and TOPSIS Note: TOPSIS method is not Fuzzy	A readiness assessment model for institutionalization of SMEs
	(Zandi & Tavana, 2011)	Overcoming the need of TOPSIS method to measure the criteria weights and performance ratings precisely in imprecise and vague phenomena.	Hybrid method based on TOPSIS, ROA, hybrid fuzzy group permutation and fuzzy quality function deployment	Agile manufacturing
	(Jalayer et al., 2018)	Maximizing the influence of the social networks by considering the multiple centrality measures.	Hybrid method based on a community detection algorithm and TOPSIS	Influence maximization in social networks
	(Xu, 2013)	Focusing on experts' weight and the interval preference orderings concept.	A TOPSIS-based approach	Selecting partner for software company and the evaluating of key factors in cooperation of enterprises
	(Maghsoudlou et al., 2016)	Using TOPSIS as a simple and fast method with limited subjective inputs and unlimited number of criteria and alternatives together with the advantages of AHP.	Hybrid AHP-TOPSIS method	Supply chain problem in congested systems
	(Zabihi et al., 2019)	Gaining a higher performance on solving the instances.	Hybrid method based on AHP and TOPSIS	Multi-skilled project scheduling

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Dev et al., 2019)	Combining the advantages of methods for example the transparent construction process in ANP and easy-to-understand process of TOPSIS.	Fuzzy ANP and TOPSIS	Information granulation of big data
	(Khoshsirat et al., 2021)	Considering both multi-objective robust possibilistic and possibilistic chance-constrained programs for the first time.	fuzzy PROMETHEE method and TOPSIS	The purchase operations among a relief organization and suppliers
	(Almomani et al., 2013)	Gaining a systematic approach instead of using conventional un- systematic methods such as Shingo's Single Minute Exchange of Dies (SMED).	Integration of AHP, PSI and TOPSIS.	Setup time reduction in PVC industry
	(Miranda-Ackerman et al., 2017)	Handling the complexity of the agro food supply chain decision problems.	Integration of LCA, GA and TOPSIS	Supply chain in orange juice agro-food cluster
	(B. Zhang et al., 2019)	Gaining global optimal solution by simultaneously solving two sub-problems and using TOPSIS for obtaining the order of the promising sub-problems.	HFGSP model including TOPSIS	Sustainable manufacturing
	(Shidpour et al., 2013)	Considering both quantitative and qualitative evaluation criteria.	MOLP model integrated to the TOPSIS method, and fuzzy AHP	Integration of new product development (NPD) process and supply chain problems
	(C. chen et al., 2021)	Comparing the results of different GA algorithms with different MCDMs.	Different GA with using TOPSIS, LINMAP, and shannon entropy	Cost of retailer and customers' waiting time
	(Darestani & Hemmati, 2019)	-	Optimization tool and TOPSIS	Ordering methods of robust optimization in supply chain management concept
	(Sianaki et al., 2018)	-	Combination of TOPSIS and Delphi with a linear optimization model	Demand response problem in the smart grid
Technological Forecasting and Social Change	(Ouenniche et al., 2018)	Overcoming the issues related to the lack a suitable framework for out-of-sample evaluation due to the TOPSIS classifiers.	Modified TOPSIS	Bankruptcy prediction

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Carayannis et al., 2018)	Addressing the earlier criticism related to the balanced scoreboard method that concerns equal weighting and aggregation of indicators.	Combining AHP and TOPSIS	Innovation Scoreboards rankings
	(Ren et al., 2017)	Using the results of three methods to gain more reliability.	Combination of the SWM, digraph model, and TOPSIS (Also BWM for determining the criteria weights)	Technologies for urban sewage sludge treatment
Journal of Energy Storage	(Anilkumar et al., 2021)	Comparing the results of TOPSIS, EDAS, MOORA, with different weights using (AHP, Entropy, etc.)	TOPSIS, EDAS and MOORA considering different criteria weights using AHP, ENTROPY and CRITIC methods	Optimum selection of PCM for a solar system
	(de Lima Silva & de Almeida Filho, 2020)	-	Using optimization problem together with LINMAP and TOPSIS separately for decision making	Designing thermal storage systems
	(Sohani et al., 2022)	Using NSGA-II for determining Pareto optimal frontier and TOPSIS for ordering the alternatives.	Combination of TOPSIS and NSGA-II techniques	Selecting best PCM for a building integrated system
	(Ahmad et al., 2020)	Using TOPSIS for its simplicity.	TOPSIS in probabilistic optimization algorithm	Allocation of energy storage systems
	(Shi & Asgari, 2022)	-	MOPSO algorithm with TOPSIS and LINMAP	Analyzing energy storage systems
	(Maleki et al., 2021)	Comparing the results of TOPSIS and VIKOR as widely used methods used with the other methods in the hybrid framework.	A novel hybrid method based on MCDM methods including VIKOR and TOPSIS and different methods such as computational fluid dynamics (CFD), NSGA-II, and artificial neural network (ANN)	Designing latent heat thermal energy storage system
Journal of Air Transport Management	(Ghorabaee et al., 2017)	Gaining more reliable results in this concept.	New hybrid method based on WASPAS, COPRAS, TOPSIS, and EDAS methods	Evaluating y the airlines
	(Feng & Wang, 2000)	Providing a simple method with an indisputable preference order.	TOPSIS and grey relation analysis	Evaluating the performance for airlines

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Table 3. Continued

Journal	Reference	Description	Method	Concept
	(Barros & Wanke, 2015)	Using TOPSIS for the first time for assessing efficiency in this sector due to its advantages through other methods.	Combination of neural networks with TOPSIS results	Assessing the African airlines efficiency
Decision Support Systems	(Conejero et al., 2021)	-	TOPSIS together with a method based on a worst-best case scenario analysis	Ranking educational and vocational training
	(Kwok & Lau, 2019)	To address the failure of the conventional TOPSIS methods to handle that sort of problem.	Vague Set TOPSIS	Hotel selection
	(Li & Lai, 2014)	Generating consensus decision analysis with unintelligible and complex data from social networks.	Integration of the TOPSIS, SNA, and IFSs	Supporting purchasing products for online users
	(Kilic et al., 2014)	Using their systematic method for the first time for EPR selection.	A fuzzy AHP with TOPSIS	Selecting ERP system
	(Zaidan et al., 2015)	Using the integrated method based on the recommendations of the relevant literature.	AHP integrated with different methods such as TOPSIS, SAW, WPM, WSM, and HAW	Software selection
Automation in Construction	(Lin et al., 2021)	Integrating the information on the influential factors, and overcoming the human errors, fuzziness, and uncertainty in collecting data using TOPSIS and MCS, respectively.	Integration of TOPSIS and Monte Carlo simulation (MCS) methods	Excavation project
	(Zhang & Pan, 2021)	Offering the advantages of TOPSIS together with fuzzy AHP.	integrated fuzzy-AHP-TOPSIS	Tower crane layout planning/ construction industry
Omega	(Bilbao-Terol et al., 2014)	Proposing an alternative formula to consider the relative importance of two distances by using the additive closeness and remoteness.	Additive -TOPSIS version	Government bond funds
	(Peng et al., 2011)	Identifying a compromised solution in conflicting rankings which is generated by different methods.	Fusion approach based on TOPSIS, PROMETHEE, WSM, and VIKOR	Ranking multiclass classification algorithms
	(Li et al., 2015)	Addressing the limit of traditional TOPSIS due to its crisp evaluation results.	TOPSIS based aggregation method using context-free grammar linguistic expression ratings	Evaluating individual research output

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Table 3. Continued

Journal	Reference	Description	Method	Concept
Transportation Research Part E: Logistics and Transportation Review	(Marchetti & Wanke, 2020)	Solving the issues related to the fact that normal TOPSIS method cannot provide details about the determinants of the scores.	Combined TOPSIS with a GA	Rail Cargo System in Brazil
	(Wei & Lee, 2021)	-	Hybrid method with an improved entropy weighted TOPSIS	Railway Express
	(Li et al., 2018)	Gaining a comprehensive evaluation.	Improved entropy TOPSIS	Selecting imported grain distribution centers in China
	(Li et al., 2018)	Using complex network theory in this concept for the first time.	Integration of qualitative methods with quantitative methods (e.g. TOPSIS)	China railway express consolidation in China
	(Sheu, 2010)	Grouping the areas affected dynamically using fuzzy clustering, then identifying relief-demand urgency using TOPSIS.	Coupling of data fusion with TOPSIS and fuzzy clustering	Relief-demand management for emergency operations
Transportation Research Part A: Policy and Practice	(Huang et al., 2018)	-	Entropy-TOPSIS method	Evaluating the performance of urban rail transit system
	(Sobhani et al., 2020)	Improving AHP with faster and better process of TOPSIS, and addressing the substantial training demands of pairwise comparison in AHP. Using qualitative (PESTLE) and quantitative methods together.	Integrating Fusions PESTLE qualitative framework with AHP-TOPSIS	Assessing UCM in transportation systems
	(Özceylan, Çetinkaya, et al., 2016)	Improving the result of TOPSIS using AHP and ANP that consider the effects of relations between criteria and alternatives.	Combining AHP-TOPSIS and ANP-TOPSIS	Evaluating the performance of logistic
	(Chen et al., 2014)	Gaining a comprehensive evaluation of attributes by combining methods. Using MGE as a suitable method for complex systems with manifold quantitative factors.	Integration of MGE and TOPSIS	Evaluating large transport terminals
	(Aljohani & Thompson, 2020)	Using easy-to-use method with efficient computations especially with many criteria and alternatives.	TOPSIS in the ranking step in a multi-criteria spatial evaluation	Ranking candidate sites

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Table 3. Continued

Journal	Reference	Description	Method	Concept
Computers in Industry	(M.-C. Lin et al., 2008)	Considering the integrated method as a suitable approach for generating a better design efficiently considering a specific customer requirements' set.	Integration of AHP and TOPSIS	Evaluating the process of customer-driven product design
	(Özceylan, Erbaş, et al., 2016)	-	Integrated framework based on GIS-ANP-TOPSIS	Evaluating Potential freight villages
	(Thong et al., 2019)	Considering different time intervals.	A new TOPSIS	Evaluating the performance of university lecturers
Mathematics and Computers in Simulation	(Yang et al., 2007)	Comparing the results of TOPSIS and a fuzzy-based method.	TOPSIS with AHP based weighting	Evaluating dynamic operator allocation
	(Yang & Chou, 2005)	Extending TOPSIS to include more than two responses and obtaining quality multi-response solutions.	A hybrid Taguchi method and TOPSIS approach	Packaging company
	(Kuo et al., 2008)	Using TOPSIS and AHP as common methods for ranking, and weighting the criteria, respectively.	TOPSIS and AHP combined with Taguchi	A multiple-processor flow shop and ceramic manufacturing
Operations Research Perspectives	(Sureeyatanapas et al., 2018)	Being applicable even for uncertain and/or unavailable assessment data and/or the criteria weights	Extended TOPSIS	Supplier selection
	(Mohanty et al., 2018)	Considering variance of criteria rating and uncertainty in decisions by using the attribute weights based on objective and subjective evaluation and using an integrated weight calculation method.	A novel method using TOPSIS, VIKOR, and PROMETHEE	Ergonomically designed office chair
Computer Standards & Interfaces	(Garg et al., 2019)	Using AHP helping decision makers to identify the relative importance of weights using a systematic way, and enabling them to add the advantages of AHP to the TOPSIS method.	Improved TOPSIS with AHP	Journal selection
	(Işıklar & Büyüközkan, 2007)	Using AHP and TOPSIS based on the methods used in the literature for performance assessment.	AHP-TOPSIS	Evaluating the alternatives of mobile phone
	(Wang & Shih, 2013)	Selecting method by analyzing the literature.	Integration of TOPSIS and DEMATEL	Evaluating prototype: example of ultrabooks development

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Table 3. Continued

Journal	Reference	Description	Method	Concept
Operations Research for Health Care	(Chalgham et al., 2019)	Dealing with complex decision problems using; Gaining advantages such as better reality, using more suitable weights, gaining more coherent data, and more time saving decisions.	AHP based Delphi combined separately with TOPSIS, ELECTRE II, and PROMETHEE II	Managing the patients in hospitals
Sustainable Futures	(R Micale et al., 2019)	Using a new approach to address complex problems.	Firefly optimization algorithm and TOPSIS	Sustainable vehicle routing
International Journal of Information Management Data Insights	(Deepu & Ravi, 2021)	Handling uncertainties using a hybrid approach.	Integration of AHP and TOPSIS	Selecting information systems in an electronic supply chain
	(Kapoor et al., 2021)	Benefiting the synergy of both methods that is recommended in many papers.	Combined AHP-TOPSIS method	Development of tribal village

Fuzzy TOPSIS Methods for Industry and Technology Concepts

This method is used by manifold authors in the industrial and technology fields from power plants to 3D TV technologies. A TOPSIS approach integrated with interval-valued intuitionistic fuzzy numbers was used by Intepe et al. (Intepe et al., 2013) for selecting the forecasting techniques for 3D TV technology. Li and Chou (Li & Chou, 2014) used a novel fuzzy TOPSIS method to elicit the evaluation criteria set for power planning models. They also conducted quantitative assessments to analyze the strategies that can influence the ranking results.

In 2016, in a comprehensive study, Zamani-Sabzi et al. (Zamani-Sabzi et al., 2016) compared ten different MCDM methods such as VIKOR, SAW, AHP, and TOPSIS under fuzzy environment. They analyzed the similarity and differences of the proposed fuzzy methods considering different factors. Their results showed that applying some of the techniques including CP, SAW, TOPSIS, and WPM were more computationally simple compared to others.

Wang and Duan (Wang & Duan, 2018) used the benefits of the intuitionistic fuzzy set and the polygonal fuzzy set to develop a TOPSIS based MCDM approach. They used this method for assessing and comparing cinemas in the entertainment industry. A research related to the military sector for assessing underwater technologies, a modified intuitionistic fuzzy and TOPSIS (Aloini et al., 2018). Different criteria were considered such as recurring costs reduction, complexity, etc. In a similar study, Cavallaro et al. (Cavallaro et al., 2019) used a modified intuitionistic fuzzy with TOPSIS method to evaluate different factors such as solar tower and parabolic solar trough in a solar power system. They used trigonometric entropy weights in their method. In this year, also Chalvatzis et al. (Chalvatzis et al., 2019) proposed an multi objective grey linear optimization problem related to the sustainable electricity generation. They used different criteria that were grouped into technical, environmental, social, and economic categories including various subcritical for each of them. They used Grey-TOPSIS method in their study and scored the generation systems.

Liu and Wang (Liu & Wang, 2019) used an ideal-TOPSIS method under hesitant fuzzy environment. They combined a specific distance measure together with reference ideal theory in this method. They evaluated five energy projects as an example to show the effectiveness of their model and compared it with traditional TOPSIS. Martín et al. (Martín et al., 2019) studied a hybrid decision

making method based on TOPSIS and fuzzy logics to determine airport shoppers' satisfaction. They identified the important factors as passengers' destination route and the place of residence. Finally in 2022, Lin et al. (Lin et al., 2022) incorporated TOPSIS method with fuzzy sets. They used a hybrid fuzzy set including hybrid fuzzy sets pythagorean and triangular fuzzy sets in this study to evaluate the risk of the excavation systems. They evaluated the performance of their proposed method using the case of excavation engineering project in Tianjin, and they determined the risk factors in this project.

Fuzzy TOPSIS Methods for Supply Cahin

In supply chain area TOPSIS method in fuzzy environment can be a suitable method for decision makers. They can apply this method to decisde about the best supplier in different companies and industries as well as to study the factors impacting the supply chain management. Foe instance, in 2006 Chen et al. (Chen et al., 2006) also used a fuzzy TOPSIS approach to determine the suitable supplier. They considered different aspects including delivery performance, flexibility, price, and quality in their study. Awasthi et al. (Awasthi et al., 2010) used a fuzzy method based on TOPSIS to rank suppliers by considering their environmental performances. Kannan et al. (Kannan et al., 2014) ranked 12 green suppliers with different fuzzy TOPSIS methods. They proposed a new fuzzy TOPSIS and compared the results of the proposed methods with two other TOPSIS methods. They then validated their method using a numerical example related to a company assembling electronics equipment in Brazil. In another article by Rao et al. (Rao et al., 2014) a supplier selection problem was also studied. they presented an index system for suppliers based on different attributes such as quality, delivery time, price, and quantity. They then used a hybrid MCDM method based on TOPSIS under fuzzy environment to rank the suppliers. They analyzed a decision-making problem for a multi-source procurement of electric coal using this method. Yue (Yue, 2016) in 2016 also used an interval-valued intuitionistic fuzzy model together with TOPSIS method for a group decision-making, and provided an example for problem for supply chain management concept.

More recently, Sari and Suslu (Sari & Suslu, 2018) aimed evaluate and compare the green performance factor of different hotel supply chain using their developed tool. They used 15 criteria, and determined their weights with the contribution of 20 hotel managers in Turkey. They used a fuzzy TOPSIS approach to rank and score the supply chains in hotels. Tseng et al. (Tseng et al., 2018) utilized a fuzzy model based on TOPSIS in the supply chain finance concept. They considered 14 different criteria in their decision-making model. For example, satisfaction of the customer and stakeholder, environmental policy, cash management, and trade credit. In 2019, Zhang et al. (H. Zhang et al., 2019) introduced a novel method based on TOPSIS in the intuitionistic fuzzy systems. They applied their method to a battery company involved in the recycling process. The aim was to choose the appropriate third-party reverse logistics provider (3PRLP). They showed that this is a suitable method to depict the fuzzy essence in this decision making problem. Yadavalli et al. (Yadavalli et al., 2019) studied a supply chain problem using an integrated model with manifold approaches. one of the main steps was to use Z-numbers in a fuzzy TOPSIS method based on the expectation of the retailors. Orji and Liu (Orji & Liu, 2020) use fuzzy TOPSIS to study different factors in manufacturing supply chain to insure the key drivers in this area to gain a long term and sustainable performance by considering the implementation of innovation-led lean approaches. Du et al. (Du et al., 2021) used TOPSIS together with grey incidence analysis. They investigated two different case studies for the selection of supplier for the complex equipment and movie recommendation to show the strong interpretability and applicability of their model.

Fuzzy TOPSIS Methods for Strategies and Management Concepts

Another area that shows the applicability of fuzzy methods is decision making problems management and strategic planning concepts. This sub-group includes different subjects such as evaluating people in organizations, location selection, project management, etc. Lai et al.(Lai et al., 1994) for example, considered a modified TOPSIS method and proposed their method by using a

water quality management problem in Bow River Valley. They used a first-order compromise method to decrease the k-dimensional objective space to a two-dimensional one. For both considered criteria, the fuzzy set theory's membership function was utilized to show their level of satisfaction. In another study, Kuo et al. (Kuo et al., 2007) used new fuzzy TOPSIS method for location selection as well.

Awasthi et al. (Awasthi, Chauhan, & Goyal, 2011) investigated a MCDM under uncertainty problem for location planning for urban distribution centers. They used a fuzzy theory to quantify the criteria. They also used a fuzzy TOPSIS method to rank the locations that can help the logistics operators to decide about the best location for implementing new distribution centers in municipal administrations projects. In this study a committee with three decision makers were formed, and the decision criteria were accessibility, security, connectivity to multimodal transport, costs, environmental impact, proximity to customers, proximity to suppliers, resource availability, conformance to sustainable freight regulations, possibility of expansion, and quality of service. Nieto-Morote and Ruz-Vila (Nieto-Morote & Ruz-Vila, 2012) used a fuzzy TOPSIS method based on fuzzy set theory to assess the alternatives of construction contractor in a building project management in Technical University of Cartagena. Ning et al. (Ning et al., 2011) also used the intuitionistic fuzzy TOPSIS to evaluate and rank the alternatives in a construction site layout planning in a case of a residential building project. In another related study, Ning et al. (Ning et al., 2016) used TOPSIS method combined with the intuitionistic fuzzy set (IFS) theory to determine the best alternative for site layout plan among different solutions in the site design step. They selected ten key attributes and find the solution that addressed the required attributes to assist site managers for efficiently select the site plan. Wan et al. (Wan et al., 2016) proposed a new fuzzy approach including triangular intuitionistic fuzzy numbers as well as using TOPSIS method for weighting. The method was used for assessing different alternatives that a venture capital company possesses for investment in its money. They compared the results of this fuzzy method with VIKOR method for group decision-making. For a haze management study, Wan et al. (Wan et al., 2018) also applied a similar method in 2018. They used an extended TOPSIS method for determining the weights and used Pythagorean fuzzy numbers (PFNs) in their study.

Deveci et al. (Deveci et al., 2017) used an interval type-2 fuzzy TOPSIS method to opt a new route at an airport in the North American region. They considered five different destinations, and analyzed what aspects could overshadow the feasibility of the new route. To evaluate water resources, Li et al. (Li et al., 2019) in 2019, evaluated the regional water resource coordination in a their study. They used hesitant fuzzy numbers for expressing the opinion of the experts. They applied a distance-based method and a hesitant fuzzy weighted averaging operator to determine the evaluators and weights of the criteria. In this study, TOPSIS, in the final step, was utilized to evaluate the results. They applied their proposed method for a case related to the Northwestern District of China. Zhang et al. (L. Zhang et al., 2019) also evaluated agents in a Multi-Source Heterogeneous Information System. They used a TOPSIS based method (by utilizing an Intuitionistic Fuzzy Value) in their evaluation and measured the comprehensive distance using a weighted Euclidean distance metric. They also compared their results with another method based on intuitionistic fuzzy TOPSIS. Faghih-Roohi et al. (Faghih-Roohi et al., 2020) aimed to evaluate and rank different risk categories such as security, weather, temperature, etc. in all of the destination pairs in Amsterdam. Their method was based TOPSIS for Failure Mode and Effects Analysis (FMEA) under an intuitionistic fuzzy environment.

Ma et al. (Ma et al., 2020) in a similar study used Key Performance Indicators (KPI) together with an MCDM method (fuzzy logic model based on TOPSIS) to select the best project portfolio. They presented a case study related to a paper-manufacturing company to show the application of their approach. Zhan et al. (Zhan et al., 2020) used a novel method based on Pythagorean fuzzy TOPSIS methodologies to handle the complicated MADM problems that cannot be solved using normal intuitionistic fuzzy and fuzzy methods. They used this method for conducting emergency plans when an unconventional emergency event happens. Li and Wei (Li & Wei, 2020) used an extended TOPSIS using hesitant fuzzy linguistic information and a sub-group weighting model for large scale DM in healthcare services. In this method they described the decision information by utilizing the Hesitant

fuzzy linguistic term sets. They also applied an example for healthcare management to examine the method. A hesitant intuitionistic fuzzy linguistic (HIFL) set also was used with TOPSIS for selecting the strategy for the location of emergency rescue facilities in China (Guo et al., 2021). Finally, Rehman and Ali (Rehman & Ali, 2021)studied the best means of transport for crude oil routes in China using a fuzzy TOPSIS method. They also used a cost beneficial to investigate the economic viability of the systems. Different criteria were considered in this study including security risks, gas emissions, energy consumption, economic costs, and time.

Integration of Fuzzy TOPSIS with Other Methods

The last category includes using Integrated fuzzy TOPSIS based methods considering different concepts including industry and technology, strategies and management, supply chain area, and location ranking. The results of the papers are summarized shortly in Table 5.

Integrated Fuzzy TOPSIS for Industry and Technology Areas

In this sub-section the articles used integrated fuzzy TOPSIS based methods in industrial and technology fields are listed. In product design and manufacturing aspects different studies focused on this method. For example, Kahraman et al. (Kahraman et al., 2007) evaluated the robot systems in different industries using a hierarchy-based new fuzzy TOPSIS. Vincent and Hu (Vincent & Hu, 2010) proposed a method for evaluating the manufacturing plants of a company producing different power-related products (such as DC/DC converters, switch power, etc.). They combined voting method (for determining the criteria weights) with fuzzy TOPSIS in this study. Kucukvar et al. (Kucukvar et al., 2014) used a fuzzy MCDM method including TOPSIS together with intuitionistic fuzzy entropy, intuitionistic fuzzy weighted geometric averaging operator, and fuzzy weighted arithmetic averaging operator methods to rank pavement alternatives that are built with different asphalt mixtures. Wang et al. (Wang et al., 2015) integrated life-cycle-assessment with fuzzy extent analysis and fuzzy TOPSIS in their study for assessing the product designs in a manufacturing company considering the environmental aspects. They used different sub-criteria for material selection, distribution, usage, and End-of-life phases to rank the products. Another novel fuzzy MCDM method was introduced in 2015 by Chen (Chen, 2015). This method, called interval type-2 fuzzy TOPSIS, were used for three different problems including car evaluation, supplier selection, and landfill site selection in this study.

In 2018, Oliveira et al. (Oliveira et al., 2018) considered six different criteria such as material selection and supplier integration, to asset 16 different alternatives for the enablers of Lean and Green for product development in small and medium enterprises using AHP and fuzzy TOPSIS. An integrated grey TOPSIS model was used in another study by Singh et al. (Singh et al., 2020) to assess the risk factor in the product lifecycle management. The criteria were selected as mismatch in required data formats, inefficient resource estimation, etc. Lin et al. (Lin et al., 2020) used a comprehensive combined method based on the integration of fuzzy AHP, game theory, and entropy weighting together with fuzzy TOPSIS. They used this model for assessing the performance of disc cutters. Fuzzy TOPSIS, fuzzy DEMATEL, and modified-ANP were integrated by Liu et al. (Z. Liu, Ming, Qiu, Qu, & Zhang, 2020) for evaluating smart product-service system in 2020. Lee et al. (Lee et al., 2021) ranked the performance of recycling outlets of different manufactures such as cement manufacturing using an integrated method based on fuzzy AHP, fuzzy TOPSIS, and the multi-objective linear programming. They used semi-structured interviews to collect data in their study. Irfan t al. (Irfan et al., 2022) used an integrated method based on AHP and Grey-TOPSIS approaches for assessing energy barriers in Indian biomass industry. AHP was used to rank the biomass energy barriers and sub-barriers in considering the allocated weights. Then, the rankings of the alternative solutions to the barriers were obtained by a Gray-TOPSIS method. They obtained “enhancing research and development (R&D) activities” as the best alternative solution.

In the aviation industry, Yeh and Chang (Yeh & Chang, 2009) developed a new fuzzy TOPSIS to assess aircraft types using eleven criteria and three super-criteria considered for that problem.

Table 4. Articles including fuzzy TOPSIS/fuzzy environment

Journal	Reference	Concept
International Journal of Production Economics	(Tseng et al., 2018)	Supply chain finance model
	(Orji & Liu, 2020)	Manufacturing sustainable supply chain by prioritizing the main innovation-led lean approaches
	(Chen et al., 2006)	Determining the suppliers' ranking order
	(Faghih-Roohi et al., 2020)	Selecting shipping lane in the context of air cargo distribution of pharmaceutical products using TOPSIS with a hesitant intuitionistic fuzzy linguistic (HIFL)
	(Awasthi et al., 2010)	Assessment of linguistic
European Journal of Operational Research	(Kannan et al., 2014)	Selecting green suppliers in an electronics equipment company in Brazil
	(Lai et al., 1994)	Bow River Valley water quality management problem by extending TOPSIS with fuzzy set theory
Mathematical and Computer Modelling	(Kuo et al., 2007)	Location selection using a new TOPSIS based method
	(Awasthi, Chauhan, & Goyal, 2011)	location planning for urban distribution centers
Computers & Industrial Engineering	(Du et al., 2021)	Supplier selection for complex equipment and movie recommendation problem based on grey incidence analysis together with TOPSIS
	(Liu & Wang, 2019)	Evaluating energy projects using ideal-TOPSIS method under the hesitant fuzzy environment
	(Intepe et al., 2013)	Selecting technique for 3D TV technology using interval valued intuitionistic fuzzy TOPSIS
	(Yue, 2016)	Supplier selection problem using interval-valued intuitionistic fuzzy with TOPSIS
	(Ma et al., 2020)	Project portfolio selection
	(H. Zhang et al., 2019)	Selecting 3PRLP by Incorporating TOPSIS with novel IF entropy
	(Wan et al., 2016)	Assessing investment options of a venture capital company using fuzzy approach with TOPSIS-based weighting
	(Wan et al., 2018)	Haze management problem with extended TOPSIS in intuitionistic fuzzy environment
	(Wang & Duan, 2018)	Evaluating and comparing cinemas using TOPSIS based on intuitionistic polygonal fuzzy sets
	(Zhan et al., 2020)	Emergency events using Pythagorean fuzzy TOPSIS
	(Li & Wei, 2020)	Healthcare management using an extended TOPSIS on sub-group weighting model and hesitant fuzzy linguistic information
	(Guo et al., 2021)	Strategies for the location of emergency rescue facilities using hesitant intuitionistic fuzzy set-TOPSIS
Technological Forecasting and Social Change	(Cavallaro et al., 2019)	Solar technology assessment using modified intuitionistic fuzzy TOPSIS and trigonometric entropy weights

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Table 4. Continued

Journal	Reference	Concept
	(Chalvatzis et al., 2019)	Sustainable resource allocation in power generation industry using grey TOPSIS
	(Aloini et al., 2018)	Assessing the advanced underwater systems using Peer IF with TOPSIS
	(Sari & Suslu, 2018)	Evaluating green performance of a hotel supply chain
Journal of Air Transport Management	(Martín et al., 2019)	Analyzing Duty-free shoppers' satisfaction based on TOPSIS and fuzzy logics
	(Deveci et al., 2017)	Airline new route selection using interval type-2 Fuzzy TOPSIS
Automation in Construction	(Lin et al., 2022)	Evaluating risk of excavation using TOPSIS with hybrid fuzzy sets
	(Nieto-Morote & Ruz-Vila, 2012)	Construction contractors' requalification
	(Ning et al., 2016)	Construction site layout problem based on intuitionistic fuzzy set is combined with TOPSIS
	(Nieto-Morote & Ruz-Vila, 2012)	Construction contractor prequalification using TOPSIS and fuzzy set theory
	(Ning et al., 2011)	Construction site layout planning using intuitionistic fuzzy TOPSIS method
Omega	(Li & Chou, 2014)	Power planning model using a novel fuzzy TOPSIS
	(Li et al., 2019)	Evaluating regional water resources using TOPSIS aggregation method and hesitant fuzzy numbers
Transportation Research Part E: Logistics and Transportation Review	(Rehman & Ali, 2021)	Crude oil imports using cost benefit analysis
Advanced Engineering Informatics	(L. Zhang et al., 2019)	Assessing the alternative agents using a novel TOPSIS with intuitionistic fuzzy
	(Zamani-Sabzi et al., 2016)	Selecting an appropriate MCDM method under a fuzzy environment considering different methods such as TOPSIS
	(Yadavalli et al., 2019)	Selecting sustainable suppliers considering customers' expectations using fuzzy-TOPSIS methodology with Z-numbers
Fuzzy Information and Engineering	(Rao et al., 2014)	Procurement of electric coal in industry in a supply chain problem

For example, they used technological advances as super-criteria, and maximum range of the aircraft and the reliability of it as the criteria. Bango and Ocampo (Bongo & Ocampo, 2017) also integrated fuzzy TOPSIS, fuzzy DEMATEL, and fuzzy ANP to solve decision problem related to selecting the best action for air traffic flow management (ATFM) for addressing the congestion of air traffic. To investigate the safety of airlines, Barak and Dahooei (Barak & Dahooei, 2018) used a fuzzy hybrid model based on the integration of fuzzy DEA, and six different MADM methods (such as fuzzy TOPSIS, fuzzy, VIKOR, and fuzzy SAW) as well. Another work in the aviation sector conducted by Kiraci and Akan (Kiracı & Akan, 2020) was a hybrid method using interval type-2 fuzzy AHP (IT2FAHP) and Interval type-2 fuzzy TOPSIS (IT2FTOPSIS) to find the best commercial aircraft. They considered three aspects including environmental, economic, and technical terms in their study.

In another article, Tanrıverdi and Lezki (Tanrıverdi & Lezki, 2021) used fuzzy TOPSIS and fuzzy AHP considering 19 different criteria to assess the strategies for air cargo carriers.

In transportation industry, for assessing the quality of metro services in Montreal, Awasthi et al. (Awasthi, Chauhan, Omrani, et al., 2011) used a multiple-step approach based on collecting data using questionnaire, and using MCDM methods for ranking. They used manifold criteria such as empathy, reliability, assurance, and responsiveness in a combined decision-making approach based on fuzzy TOPSIS and the linguistic ratings. Furthermore, Celik et al. (Celik et al., 2013) assessed the satisfaction of customers in public transportation in Istanbul using a novel fuzzy method based on TOPSIS and grey relational analysis (GRA). Also, in a problem related to assessment of the sustainability of urban mobility projects, Awasthi et al. (Awasthi et al., 2018) in 2018, used fuzzy TOPSIS, fuzzy GRA, and fuzzy VIKOR as MCDM methods, and the final veto results based on them. In another study fuzzy TOPSIS and fuzzy evidential reasoning (ER) method were embedded in to assess vulnerability of ports using different factors such as storage system, navigation system, and loading/uploading systems, etc. (Cao & Lam, 2019).

In education industry, Yuan and Luo (Yuan & Luo, 2019) used a novel IFE to address history studies shortcomings neglecting uncertainty and hesitancy degrees in an example related to recruiting a teacher among four alternatives. They used TOPSIS and Hamming distance finally to obtain the alternatives' similarity degree. A novel fuzzy MCDM approach also used by Nojavan et al. (Nojavan et al., 2021) using fuzzy SERVQUAL questionnaires, fuzzy AHP, fuzzy TOPSIS, and fuzzy DEA to assess the performances of educational units in Iran. In the tourism industry also some articles focused on using integrated and modified fuzzy TOPSIS methods. for example, factors affecting the medical tourism can be investigated using decision making methods. In a study in 2019, the interrelationships between the factors were studied, and the importance levels of factors were determined using fuzzy DEMATEL and fuzzy TOPSIS methods. Different criteria were used such as international healthcare collaboration, specialization and the quality of services (Nilashi et al., 2019). Fuzzy hierarchical TOPSIS was used together with DINESERV framework in a study by Luo and Bellomo (Lupo & Bellomo, 2019) using five different dimensions including tangibles, assurance, empathy, reliability and responsiveness as criteria for three restaurants in the University of Palermo. DINESERV is a theoretical framework used for the restaurant services' quality.

In healthcare industry, a novel extended fuzzy TOPSIS also was used by Li and Wei (Li & Wei, 2020) in 2020. They applied Hesitant fuzzy linguistic term sets (HFLTSs) for describing the decision information in their research. Karasan et al. (Karasan et al., 2022) in 2022, developed a new framework for assessing the clinics' quality levels in hospitals. For this, they used an integrated fuzzy method using Pythagorean Fuzzy TOPSIS method together with a fuzzy Inference System (FIS), and they also set five main criteria with different sub-criteria for the case study of a private hospital. A new hybrid fuzzy approach based on fuzzy Delphi method, fuzzy AHP, and fuzzy TOPSIS was conducted by Gupta et al. (Gupta et al., 2022). They used this method for healthcare risk management during pandemic such as COVID-19 situation.

Finally, in banking and financial industry, Dinçer and Yüksel (Dinçer & Yüksel, 2019) used a method based on fuzzy TOPSIS together with fuzzy ANP, fuzzy VIKOR, and Monte Carlo Simulation using different dimensions for the performances of the banks. In this paper, fuzzy ANP was applied as the weighting method. On the other hand, fuzzy TOPSIS and fuzzy VIKOR were used for ranking the banks. Monte Carlo Simulation also provided the stochastic values in this study.

In technology fields also different studies focused on integrated fuzzy TOPSIS as well. Sohaib et al. (Sohaib et al., 2019) used a novel 2-tuple fuzzy linguistic MCDM method based on TOPSIS and considering a technology-organization-environment (TOE) framework. They used this method for evaluating the cloud-based e-commerce systems in small/medium-sized organizations considering privacy, security, reliability, etc. In knowledge-intensive crowdsourcing (KI-C), a combined method based on fuzzy DEMATEL and fuzzy TOPSIS was used to evaluate participants. In this study, fuzzy TOPSIS was used for determining the priorities of the participants (Zhang & Su, 2019). In a specific

Iranian Telecommunication Company a combined MCDM method was used for selecting the most suitable approach for acquiring interactive TV technology by Dahooie et al. (Dahooie et al., 2021). Manifold fuzzy methods such as fuzzy WASPAS, fuzzy TOPSIS, fuzzy VIKOR, and fuzzy SAW were integrated in this study. Pythagorean Fuzzy TOPSIS (PFTOPSIS) integrated with Pythagorean Fuzzy AHP (PFAHP) were used by Bulut and Özcan (Bulut & ÖZCAN, 2021a) for the first time. They used this technique for decision making and assessed a system based on the integration of battery storage technology and a particular combined power plant. In another work, they also used similar technique for assessing the technology performance of a specific storage system (Bulut & Özcan, 2021b). Hacioglu et al. (Hacioglu et al., 2021) integrated fuzzy AHP and fuzzy TOPSIS to assess different strategies for cryptocurrency mining called as cloud mining, home mining, and hosted mining. Linguistic fuzzy TOPSIS and DEMATEL also were used for ranking and criteria weighting, respectively; by Elibal and Özceylan (Elibal & Özceylan, 2022) for evaluating Industry 4.0 maturity models considering Total Quality Management (TQM) concept and using manifold criteria and sub-criteria.

Integrated Fuzzy Methods for Strategic and Management Decisions

The articles reviewed in this sub-section used integarted fuzzy systems for decision making in the management, planning, evaluation in companies, etc. Büyüközkan et al. (Büyüközkan et al., 2008) in 2008 investigated the strategic alliance partner selection using an integrated fuzzy MCDM method (fuzzy AHP-fuzzy TOPSIS). They identified the main criteria and sub-criteria for evaluating the partners. They took, different Turkish logistics, as an example; and ranked the partners based on 10 criteria such as financial stability, similar size and value goals. In 2016, Garg (Garg, 2016) also used fuzzy TOPSIS with AHP for evaluating and selecting the strategic alliance partner in the airline industry. Joshi and Kumar (Joshi & Kumar, 2016) proposed an extended TOPSIS-based method benefitting the advantages of TOPSIS together with Choquet integral operator and also using interval-valued intuitionistic hesitant fuzzy sets (IVIHFS) for group decision making. They used this method for a human resource development process and for recruiting a manager from four alternatives considering reliability, demanding, and knowledge criteria. Lin et al. (Y.-H. Lin et al., 2008) applied both the Minkowski distance function and the concept of grey number operations to enhance traditional TOPSIS and gain the modification of the extension of this method. They applied their model to study a subcontractor selection problem in construction management. In another similar concept, a project selection problem was conducted by Khalili-Damghani and Sadi-Nezha (Khalili-Damghani & Sadi-Nezhad, 2013) using a TOPSIS based fuzzy goal programming (FGP) method. Different economic, social, and environmental factors were used together with organizational readiness, investment risk, and strategic alliance in this study. Furthermore, Meng and Zhang (Meng & Zhang, 2014) studied optimal bidding schemes under a fuzzy environment. They used TOPSIS method together with the consistency principle and the Shapley function for gaining optimal weight vectors. For assessing green operations initiatives Wang (Wang, 2015) used an integrated method for decision making process including fuzzy TOPSIS, fuzzy Delphi, and fuzzy AHP. They used operations resources, organizational and environmental performances as the main dimensions including sub-criteria. Roszkowska and Wachowicz (Roszkowska & Wachowicz, 2015) used a modified fuzzy TOPSIS algorithm for the negotiation problems and ranking the negotiation offers to prevent rank reversal of the traditional method. Walczak and Rutkowska (Walczak & Rutkowska, 2017) used a modified fuzzy TOPSIS method for ranking the projects for participatory budget. They used criteria such as estimated and future costs, location, and beneficiaries for this problem. Bostancı and Erdem (Bostancı & Erdem, 2020) used an integrated method including fuzzy DEMATEL and fuzzy TOPSIS methods considering 26 criteria for investigating the satisfaction levels of citizen with municipality services in Osmaniye, Turkey.

Ahmed and Ali (Ahmed & Ali, 2020) proposed different models in their study related to the scheduling of the operating rooms in the hospitals. They solved a decision-making problem using a

fuzzy TOPSIS method with nine criteria (such as communication skills, age, gender, reputation, etc.) integrated with the mixed linear integer programming (MILP) to optimize the scheduling results. For this purpose, they quantified the preferences of patients to surgeons. In the next step, they used the results of TOPSIS in an optimization problem based on optimum daily surgery schedule. In a two stage dynamic study, Tavana et al. (Tavana et al., 2020) used fuzzy TOPSIS with mixed integer linear programming approach for a complex multi criteria problem to select the best project with manifold stakeholders. In this study, they used fuzzy TOPSIS to evaluate and rank the portfolios/projects, and then the obtained scores from TOPSIS were used in a bi-objective mixed-integer linear program for the optimization step with the objective of minimum cost considering the optimization of employee development, their employee skill, synergy. They examined a case study using different criteria such as technical and execution capability in their fuzzy model.

Strategic planning strategies can be conducted by decision making methods for different industries and companies as well. Dincer et al. (Dincer et al., 2016) used a hybrid method including fuzzy AHP and fuzzy TOPSIS to rank the alternatives that an industry for portfolio investments. An intuitionistic fuzzy OWA–TOPSIS approach was proposed by Wang et al. (Wang et al., 2016) in 2016. For validating their model, they used a numerical example related to assess and rank collaborative manufacturing enterprises for an equipment enterprise. For partner selection in product development, An integrated fuzzy-based method was used by Büyüközkan and Güleryüz (Büyüközkan & Güleryüz, 2016) to select partner in product development problems. They combined Intuitionistic Fuzzy TOPSIS and Intuitionistic Fuzzy AHP for this study considering three criteria categories (partner, collaboration, and product development-based categories) with manifold sub-criteria. Sirisawat and Kiatcharoenpol (Sirisawat & Kiatcharoenpol, 2018) used fuzzy AHP for assigning the weights, and fuzzy TOPSIS for ranking the barriers in a problem related to the assessing of reverse logistics in an electronic industry. This concept considers the strategies for minimizing the end-life wastes and gaining the efficient utilization of the resources. A risk-based fuzzy TOPSIS method was presented by Seiti and Hafezalkotob (Seiti & Hafezalkotob, 2019), and was utilized in steel mill industry in a company in Iran to determine the best replacement time in a preventive maintenance planning program. They used different criteria including safety, downtime, and expected time function for this purpose. For product planning problems under a fuzzy environment, Ping et al. (Ping et al., 2020) applied a combined method based on maximum entropy theory and TOPSIS in the weighting of the objectively of the experts.

Integrated Fuzzy Methods in Supply Chain

Sheu (Sheu, 2008) used an integrated decision making method for global supply chain and logistics management problems using fuzzy-AHP, fuzzy-MCDM and TOPSIS, and developed an adaptive neuro-fuzzy inference system (ANFIS). In this study, after applying fuzzy-AHP and fuzzy-MCDM procedures, TOPSIS and the fuzzy-weighted criteria calculated from the previous steps were employed to develop respective fuzzy logic rules to identify global logistics and their features, as well as investigating and assessing them. Lin and Chang (Lin & Chang, 2008) used a fuzzy approach to evaluate customers/buyers. They first determined the produced orders along with the production quantity and the reference amount for price reduction using fixed and flexible mixed integer programming MIP models, then they used a fuzzy approach based on TOPSIS was used to rank the values of customers segmented by considering different criteria, and the results were applied to adjust the rates of the pricing formula. The closeness coefficients of the negative-ideal solution for satisfaction grades of orders and the closeness coefficients of the positive-ideal solution for ranking values of buyers are calculated and used as the adjusting rates in the segmented pricing formula.

Chen and Yang (Chen & Yang, 2011) used an integrated fuzzy method based on fuzzy TOPSIS and fuzzy AHP for supplier selection problems. They proposed the method for example in architecture industry for selection of the supplier for materials such as cement. They considered different attributes such as risk, delivery time, etc. for the problem. Jolai et al. (Jolai et al., 2011) integrated multi-period goal programming and fuzzy TOPSIS to assess the suppliers of products when considered two different

goals as total available periodic budget and value of purchasing. Singh (Singh, 2014) in 2014 focused on a supplier selection problem to allocate the customers' demands using a hybrid method based on the fuzzy TOPSIS and the mixed linear integer programming (MILP). Yue and Jia (Yue & Jia, 2015) proposed extended TOPSIS and fuzzy TOPSIS methods to handle the hybrid intuitionistic fuzzy information, and applied the method for a supplier selection problem. An integrated fuzzy MCDM approach also was used by Uygun and Dede (Uygun & Dede, 2016) using fuzzy DEMATEL, fuzzy ANP, and fuzzy TOPSIS for evaluating the performance of green supply chain management in alternative companies. Lima-Junior and Carpinetti (Lima-Junior & Carpinetti, 2016) used fuzzy TOPSIS as the MCDM method and combined it with a combined fuzzy TOPSIS with a Supply Chain Operation Reference (SCOR) (which was used in order to gain the performance metrics) to evaluate the suppliers and supply chain. Different criteria were considered for the cost and delivery performance dimensions such as returns costs, risk rating of the suppliers, etc. An allocation and green supplier selection problem were conducted by Hamdan and Cheaitou (Hamdan & Cheaitou, 2017) using a three-step approach. Firstly, they used fuzzy TOPSIS, and then the analytic hierarchy process in their study. Then the output of the stages was utilized for a specific linear programming model.

For problems related to the order allocatiom, and the selection of the suppliers, Mohammed et al. (Mohammed, Harris, & Govindan, 2019) used a hybrid method based multi criteria decision making and fuzzy multi objective optimization (FMOO). As the MCDM methods they applied an integrated approach using fuzzy AHP and fuzzy TOPSIS based on three different sets of criteria (social, green, and conventional) with manifold sub-groups. Another study by Mohammed et al. (Mohammed, Harris, Soroka, et al., 2019) investigated the optimal number of facilities in the green supply chain field using a hybrid MCDM-FMOO (fuzzy multi objective optimization)approach. In this fuzzy programming model, they used a fuzzy AHP method for assigning the weights, and fuzzy TOPSIS in the final step to select the final Pareto solution. Gupta et al. (Gupta et al., 2019) used fuzzy AHP and three different methods including WASPAS, TOPSIS, and MABAC integrated with fuzzy set theory in a green supplier selection problem. They used different criteria such as pollution control and environmental management system in their study. Furthermore, in the sustainable agrifood supply chain field, Liu et al. (Liu et al., 2019) used the triple bottom line (TBL) concept including social, environmental, and economic dimensions. They integrated triangular fuzzy numbers with TOPSIS and AHP in their research.

Also, in another article in the supply chain sector in steel industry fuzzy TOPSIS was used together with BWM method (Oroojeni Mohammad Javad et al., 2020). Ahmad et al. (Ahmad et al., 2022) investigated an under uncertainty problem related to the planning of the sustainable pharmaceutical supply chain. The objectives were considered based on maximum customer services, minimum costs and environmental impacts. They used fuzzy TOPSIS to rank the solutions, they also used other multi criteria methods such as co-efficiency of variation to select the best solution. They obtained that by increasing coverage distance, the company can obtain the loyalty of customers, and also introduced customer satisfaction as an important factor for sustainable planning in the supply chain.

Ranking Countries, Cities, Locations, etc.

Here the focus would be on the papers used integrated methods for ranking location, cities, countries, etc. based on different criteria. Wang et al. (Wang et al., 2007) proposed a fuzzy MCDM method for selecting an expatriate host country. They combined the concept of grey relationship model with TOPSIS. They also used fuzzy AHP to identify the weights. They suggested some correlations to correct the issues related to obtaining more than one final decision alternative (that could be even not a Pareto optimal). Chen and Tzeng (Chen & Tzeng, 2004) investigated a fuzzy MCDM problem based on combining the grey relation for an expatriate host country selection problem for a specific company. They used fuzzy AHP to identify the weights. Different criteria were used such as family, environmental, and employee personal factors. For selection of international distribution centers location, Kuo and Liang (Kuo & Liang, 2011) used new hybrid approaches using combining of

different methods such as DEMATEL, TOPSIS, and Fuzzy ANP. In this study, they used TOPSIS concept to calculate the fuzzy synthetic performance of the ideal and negative ideal. They also used fuzzy SAW and fuzzy TOPSIS for comparison. They used this method for ranking six alternatives for port in different locations such as Taiwan, China, and Korea considering different criteria including import/export volume, location resistance, etc.

The best location for a specific solar power plant was studied by using an integrated method based on AHP and fuzzy TOPSIS by Sánchez-Lozano et al. (Sánchez-Lozano et al., 2015). They also compared their proposed method with the results of a ELECTRE-TRI-based method. Roh et al. (Roh et al., 2015) investigated the strategies for warehouses prepositions using a two-stage method based on AHP and fuzzy TOPSIS. A facility location selection study by Essaadi et al. (Essaadi et al., 2019) was conducted in 2019. They used a modified fuzzy TOPSIS method.

DISCUSSION

The previous section aimed to provide a comprehensive literature review on TOPSIS decision making method. After reviewing the articles based on the TOPSIS method applied in them as well as the application area and concepts of the articles, this section provides different results gathered from the previous section. In the initial search 301 papers were identified based on "Siencedirect" database. As the search filter based on publication titles with more than one article, the number of 274 articles in different publications are chosen. The publication titles are shown in Figure 3. Then, the articles were analyzed to choose the related ones. Finally, 240 journal and conference articles were selected in this study.

Figure 4 shows the number of papers in some of the main journal/conference publications based on the method used. It can be shown that most of the papers applied modified/integrated or integrated fuzzy methods in their studies. Figure 5-8 show the number of papers in different concepts in each TOPSIS method category. The distribution of articles in different categories is also shown in Figure 9. It can be clearly seen that, most of the studies applied modified/integrated methods followed by fuzzy integrated with 103 and 72 papers, respectively.

The integrated decision-making methods reviewed in this study, different methods were used for gaining a combined framework. Here, as the number of methods used in the integrated systems is high, the focus is on the main and more common MCDM methods (including their both normal and fuzzy forms) such as AHP, ANP, PROMETHEE, ELECTRE, SAW, DEMATEL, VIKOR, WASPAS, and BWM, although some methods are found just in one of the categories (integrated or fuzzy integrated). Figures 2 and 3 provide the methods used in the integrated frameworks with TOPSIS.

TOPSIS is a widely used multi-criteria decision-making method, but its implementation is not without challenges. Critics point to its sensitivity to weight selection, which can introduce bias, and subjectivity in normalization, impacting the reliability of results. Assumptions of linearity in relationships between criteria and alternatives may not hold in real-world scenarios, and the method lacks built-in sensitivity analysis to assess robustness to changes in weights or normalization methods. Moreover, handling uncertainty and trade-offs effectively remains a challenge, as TOPSIS assumes certainty in data and does not explicitly consider trade-offs between criteria. Additionally, the complex mathematical process underlying TOPSIS rankings may lack transparency, hindering stakeholders' understanding and trust in the results. These limitations call for careful consideration of the decision context, transparent methodology, robust sensitivity analysis, and integration of techniques to address uncertainty and trade-offs, ensuring appropriate application and reliability in practice.

CONCLUSION

This study aimed to discuss TOPSIS decision making methods. For this, a short description and history of multi criteria decision making by using TOPSIS were provided. Then, the applications of

Table 5. Articles including integrated fuzzy TOPSIS-based

Journal	Reference	Description	Method	Concept
International Journal of Production Economics	(Lima-Junior & Carpinetti, 2016)	Not limiting the number of supplier and criteria, and addressing the issues related to the rank reversal and null weights.	Fuzzy TOPSIS is combined with an the SCOR model	Evaluating and manage suppliers
	(Oliveira et al., 2018)	Fitting well with many criteria and addressing the ambiguity in the model by considering vulnerability and uncertainty vagueness in input data.	AHP-Fuzzy TOPSIS	Evaluating the Lean and Green for new products development
	(Roh et al., 2015)	this approach helped the decision-makers to prioritize the various factors through the AHP and fuzzy-TOPSIS	A two-stage AHP and fuzzy-TOPSIS methodology	Strategic locations
	(Singh et al., 2020)	Considering the uncertainty and subjectivity of inputs using a grey environment.	Integrated grey DEMATEL-based ANP and grey TOPSIS techniques	PLM systems' implementation
	(Büyüközkan et al., 2008)	Using fuzzy logics to consider subjective considerations.	Integrated fuzzy AHP-fuzzy TOPSIS	Selecting strategic partners
	(Lee et al., 2021)	Using TOPSIS in order to its simplicity, widely use, and accurate results in that concept.	Integrating fuzzy AHP, fuzzy TOPSIS, the multi-objective linear programming, and semi-structured interviews	Ranking recycling outlets
	(Mohammed, Harris, & Govindan, 2019)	Using an original integrated mode, and using fuzzy TOPSIS to cope with the dynamic nature of the preferences of decision maker.	Fuzzy AHP-Fuzzy TOPSIS and FMOO	Selecting supplier and ordering in an allocation problem.
European Journal of Operational Research	(Walczak & Rutkowska, 2017)	-	Modified fuzzy TOPSIS	Rankings for participatory budget projects
	(Roszkowska & Wachowicz, 2015)	Changing the traditional fuzzy TOPSIS method to score the offers that are outside of the negotiation space that the negotiator defines them independently and subjectively.	Modified fuzzy TOPSIS	Scoring the negotiation offers
	(Wang et al., 2015)	Gaining the merits of hierarchical structure superiority together with simplicity of TOPSIS considering the uncertainty and vagueness.	Integrates Fuzzy Extent Analysis and Fuzzy TOPSIS	Developing green products

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Yeh & Chang, 2009)	Aiming to extend the optimality degree concept to consider the weights of criteria together with the distance measurement.	A new Fuzzy TOPSIS	Selecting aircraft
	(Joshi & Kumar, 2016)	Obtaining the merits of TOPSIS and Choquet integral operator and using a more flexible method for hesitant information called IVIHFS.	Extended TOPSIS method using Choquet integral operator and IVIHFS	Recruiting a manager
	(Sheu, 2008)	-	Hybrid neuro-fuzzy method based on integrating Fuzzy-MCDM, TOPSIS, and ANFIS techniques	GL operational modes in the supply chain concept
	(Lin & Chang, 2008)	Dealing objectively with pricing process and order selection.	Fuzzy TOPSIS and MIP	Order selection and pricing of manufacturer (supplier)
Mathematical and Computer Modelling	(Chen & Yang, 2011)	Integrating methods to address their demerits, and also improving them using a fuzzy form.	FAHP and FTOPSIS	Selecting the supplier
	(Chen & Tzeng, 2004)	Considering the method as more appropriate in that concept.	Combined model based on grey relation model, TOPSIS (with fuzzy hierarchical evaluation), and using FAHP as weighting method	Expatriate host country selection
	(Kuo & Liang, 2011)	Easily finding the best alternative under fuzzy environment with subjective judgments.	Hybrid approach including different methods such as TOPSIS, Fuzzy ANP, DEMATEL	Selecting the location of international distribution centers
	(Wang et al., 2007)	Suggesting some correlations to correct the issues related to obtaining more than one final decision alternative (that could be even not a Pareto optimal).	Grey TOPSIS weighted by fuzzy AHP method	Selection of the host country
Socio-Economic Planning Sciences	(Nojavan et al., 2021)	Introducing a new hybrid approach methods for filling the gap in the education concept.	Hybrid method based on FTOPSIS, FSERVQUAL, FDEA, and FAHP	Evaluating the performance of educational units in Iran
	(Karasan et al., 2022)	-	Distance-based Pythagorean Fuzzy TOPSIS, and FIS	Measuring the quality of health care service
	(Bostancı & Erdem, 2020)	-	FDEMATEL and FTOPSIS	Evaluating the municipal service quality

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Ahmad et al., 2022)	Using different methods to select the best compromise solution set.	Fuzzy TOPSIS with other methods such as degree of desirability, baseline design, and co-efficient of variance	Pharmaceutical supply chain
Computers & Industrial Engineering	(Lupo & Bellomo, 2019)	Using the integrated model to identify best practices as well as weaknesses of delivered services.	Integrating the DINESERV model with the fuzzy hierarchical TOPSIS	Evaluating quality of restaurant services
	(Nilashi et al., 2019)	Integrating two widely-used and efficient method based on the literature.	DEMATEL and Fuzzy TOPSIS methods	Adoption of medical tourism in Malaysia
	(Seiti & Hafezalkotob, 2019)	Determining the proper replacement time that is applicable where time failure related information is scant.	Fuzzy R-TOPSIS methodology	Maintenance planning in rolling mill company
	(Wang & Duan, 2018)	Addressing the issues of incomplete and shortcomings of inaccurate information descriptions traditional multi attribute methods.	TOPSIS based on intuitionistic polygonal fuzzy sets	Evaluating and comparing cinemas
	(Sirisawat & Kiatcharoenpol, 2018)	Using hybrid method based on the literature and fuzzy concept to manage the uncertainty and vagueness of human data which is difficult to calculate using exact values.	Fuzzy AHP and fuzzy TOPSIS	Strategies for reverse logistics in the electronics industry
	(Mohammed, Harris, Soroka, et al., 2019)	Using MCDM methods to gain the weights of enablers together with conducting in a fuzzy optimization model to maximize resilient value.	Integration of Fuzzy AHP, TOPSIS, and multi-objective optimization	Designing of the green supply chain network
	(Wang et al., 2016)	Analyzing the merits and demerits of aggregation methods considered in the fuzzy OWA-TOPSIS integrated method.	Intuitionistic fuzzy OWA–TOPSIS	Evaluating collaborative manufacturing enterprises
	(Awasthi, Chauhan, Omrani, et al., 2011)	Using fuzzy set theory to address the uncertainty and vagueness in system arising from the quantitative information lacks.	A hybrid approach based on SERVQUAL and fuzzy TOPSIS	Evaluating the quality of services in urban transportation systems
	(Essaadi et al., 2019)	Postponing the process of defuzzification until the reasoning end, and enabling the experts to identify the fuzziness of an evaluation, and make them possible to identify wrong evaluation.	Modified version of Fuzzy TOPSIS	Selecting the location of global logistic hubs within Africa

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Vincent & Hu, 2010)	Using the Fuzzy method due to its understandable and rational, simple mathematical concept, and capability use independently determined importance weights together with comparison procedure.	Combined method based on the voting method and fuzzy TOPSIS	Evaluating multiple manufacturing plants performance
	(Büyüközkan & Güleryüz, 2016)	Using the proposed integrated approach for partner selection for the first time.	Integrated approach based on IF AHP and IF TOPSIS	Selecting the product development partner
	(Yue & Jia, 2015)	Addressing the problem related to the intervals information loss in about intervals in IVIFNs using a GDM direct method.	Decision problems with hybrid IF information based on extended TOPSIS	Example of a supplier selection problem
	(Gupta et al., 2019)	Comparing the results of fuzzy integrated techniques.	Different fuzzy approach based on MABAC, WASPAS, AHP, and TOPSIS	Selecting green supplier in automotive industry
	(Uygun & Dede, 2016)	Developing a new hybrid approach in their concept using fuzzy DEMATEL for gathering the ideas of group and addressing cause/effect relationship in complex systems, fuzzy ANP to address the interrelation among criteria or factors, and fuzzy TOPSIS for ranking them.	Fuzzy TOPSIS, fuzzy DEMATEL, and fuzzy ANP	Evaluating green supply chain management performance
	(Kahraman et al., 2007)	Developing a TOPSIS based method considering the attributes' hierarchy similar to AHP.	Fuzzy hierarchical TOPSIS	Industrial robotic systems
	(Chen, 2015)	Using an easy-to-use and effective fuzzy method with valid results due to its ability to address ambiguous information and imprecise.	IT2FTOPSIS	Supplier and landfill site selection, and car evaluation problems
	(Gupta et al., 2022)	Considering both subjective and objective aspects using the novel proposed framework.	Fuzzy TOPSIS, fuzzy Delphi, and fuzzy AHP	Distinguishing vulnerable regions for COVID-19 transmissions
	(Liu et al., 2019)	Addressing the issue of existing methods based on fuzzy numbers and TOPSIS that neglects objective data by handling subjective and objective data as well as qualitative and quantitative criteria.	Fuzzy numbers with AHP and TOPSIS	Agrifood supply chain

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Lin et al., 2020)	Considering both qualitative and quantitative criteria.	Combination of game theory, fuzzy AHP, and entropy weighting with fuzzy TOPSIS	Evaluating and selecting disc cutter
	(Hamdan & Cheaitou, 2017)	Using fuzzy TOPSIS that has simple process, no inconsistency issues, and covers uncertainties, using AHP for weighting with no inconsistencies involved, and using optimization model to minimize costs, and maximize the selected suppliers' performance weights.	a combination of optimization tools with AHP and fuzzy TOPSIS	Order allocation and dynamic green supplier selection.
	(Liu et al., 2020)	Using DEMATLE and modified-ANP to clarify interrelations and weights and using TOPSIS to gain more realistic modeling form.	hybrid approach based on fuzzy TOPSIS, fuzzy DEMATEL, and modified-ANP	Evaluating smart product-service systems
	(Sohaib et al., 2019)	Proposing a useful method for all MCDM problems.	novel 2-tuple fuzzy linguistic method based on TOPSIS and TOE framework	Assessing the factors related to cloud-based e-commerce in SMEs
	(Khalili-Damghani & Sadi-Nezhad, 2013)	Benefiting TOPSIS compromise property helping to gain high quality results.	TOPSIS based FGP	Selecting sustainable projects
	(Yuan & Luo, 2019)	Considering a new fuzzy method to address the demerits of some other methods in providing unreasonable preference order.	Using a novel fuzzy based method with TOPSIS and Hamming distance for ranking	Recruiting a teacher
	(Meng & Zhang, 2014)	Dealing with uncertain MAGDM in interactive conditions that the information of the weights is incomplete.	Shapley function, consistency principle, and TOPSIS	Optimal bidding schemes
	(Sánchez-Lozano et al., 2015)	Choosing fuzzy TOPSIS based on the literature and integrating it with AHP to address complex problems.	Integration of AHP and fuzzy TOPSIS	Evaluating the locations of the solar thermoelectric power plants
	(Zhang & Su, 2019)	Using an effective, suitable, and easy-to-use method in their concept.	Combination of fuzzy DEMATEL and fuzzy TOPSIS	Prioritizing the participants in KI-C

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Li & Wei, 2020)	Aggregating the problem into sub-clusters and benefiting the merits of the proposed weighting method.	Extended TOPSIS based on hesitant fuzzy linguistic information and sub-group weighting	Evaluating in healthcare industry
	(Tavana et al., 2020)	-	fuzzy TOPSIS and mixed MIP	Project selection
Technological Forecasting and Social Change	(Irfan et al., 2022)	Using grey TOPSIS to execute the prioritization of the best alternative solutions.	Integration of AHP and Grey-TOPSIS approaches	Energy barriers in Indian biomass industry
	(Elibal & Özceylan, 2022)	Because of the critics about TQM concept for having an inadequate theoretical foundation and highly expert insight dependent nature, fuzzy logic principles have been used.	linguistic fuzzy TOPSIS with DEMATEL	Comparing the maturity models for Industry 4.0 considering TQM concept
	(Wang, 2015)	Proposing an effective and systematic method with rational results to address the literature gap for a systematic approach in their concept.	Hybrid model based on fuzzy TOPSIS, fuzzy Delphi, fuzzy and extent analysis	Evaluating industries' green operations initiatives
	(Dahooie et al., 2021)	Using an appropriate method for their study condition, allowing simultaneous attention to all the pivotal aspects.	a combined model based on ARAS-fuzzy, fuzzy WASPAS, fuzzy SAW, fuzzy TOPSIS, fuzzy MABAC, and fuzzy VIKOR	Choosing the right method in the process of technology transfer
Journal of Energy Storage	(Bulut & ÖZCAN, 2021a)	Using the integrated method for the first time for technology integration.	Combination of PFAHP and PFTOPSIS	Integration of technologies
	(Bulut & Özcan, 2021b)	Providing stronger DM advantages in the wide scales of evaluation using the hierarchical structure.	Combination of PFAHP and PFTOPSIS	Assessing stakeholder and technology in battery energy storage system
Journal of Air Transport Management	(Kiracı & Akan, 2020)	Obtaining more accurate result in uncertain environment by giving a more specific solution from a cluster.	Hybrid method based on IT2FAHP and IT2FTOPSIS	Evaluating aircraft
Journal of Air Transport Management	(Garg, 2016)	Incorporating and reducing uncertainty using fuzzy environment in real life problems.	Combination of AHP and fuzzy TOPSIS	Evaluating and selecting the strategic alliance partner in the airline industry
	(Bongo & Ocampo, 2017)	-	Fuzzy set theory integrated to crisp MCDM methods, such as of TOPSIS, DEMATEL, and ANP	Managing air traffic flow

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Table 5. Continued

Journal	Reference	Description	Method	Concept
	(Tanrıverdi & Lezki, 2021)	Overcoming the uncertain situations and ambiguous concepts using frequently used fuzzy methods happening in air cargo industry.	Integrating FTOPSIS based on FAHP with the Porter's five forces framework	Assessing strategies for air cargo carriers
	(Barak & Dahooei, 2018)	Using a fully fuzzy system (based on fuzzy set theory) to address vagueness inherent and imprecision safety assessment studies by experts' subjective assessment.	Hybrid method based on fuzzy SAW, fuzzy MULTIMOORA, fuzzy VIKOR, fuzzy TOPSIS, COPRAS-F, and ARAS-F	Evaluating airlines' safety levels
Decision Support Systems	(Hacioglu et al., 2021)	Using AHP as a widely used method integrated with fuzzy TOPSIS as an efficient method to cope with uncertainty and ambiguity.	Integrating AHP and fuzzy TOPSIS	Crafting a cryptocurrency mining strategy
	(Dincer et al., 2016)	Using a hybrid method to address the complex problem in their study.	a hybrid method based on fuzzy AHP and fuzzy TOPSIS	Assessing investors' perceptions for the selection of industry
Automation in Construction	(Kucukvar et al., 2014)	-	Integrated method based on TOPSIS, fuzzy entropy method, the intuitionistic fuzzy weighted arithmetic, and intuitionistic fuzzy weighted geometric averaging operators	Ranking the sustainability performance of pavements
	(Y.-H. Lin et al., 2008)	Adopting the weighted Minkowski distance function to overcome the issue of TOPSIS related to doubling the impacts of the weighting of the attributes on the separation measures and using grey analysis to address the uncertainty of evaluations.	Modified and extended TOPSIS using grey numbers and the weighted Minkowski distance function	Construction management

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Table 5. Continued

Journal	Reference	Description	Method	Concept
Transportation Research Part E: Logistics and Transportation Review	(Celik et al., 2013)	Advantaging the merits of all the methods by effectively solving complex inter-relationships between multiple performance characteristics by using GRA and benefiting the simple process coping with indisputable preference order in TOPSIS, with flexibility and applicability of Type-2 fuzzy to address uncertainties.	Integrating a novel IT2FTOPSIS with GRA method	Customer satisfaction in public transportation
Transportation Research Part A: Policy and Practice	(Awasthi et al., 2018)	Using more than one method to address the issue of gaining different rankings by using different methods.	Veto results of fuzzy GRA, fuzzy TOPSIS, and fuzzy VIKOR	Evaluating the sustainability of urban mobility projects
	(Cao & Lam, 2019)	Applying ER to avoid losing information in fusion process and gain efficient performance in fusing different data formats together with advantages of fuzzy TOPSIS.	Embedding fuzzy TOPSIS and fuzzy ER	Assessing the vulnerability of ports
Advanced Engineering Informatics	(Ping et al., 2020)	-	A novel integrated method in fuzzy system combined with maximum entropy theory weighting and TOPSIS	Product development and design planning
Mathematics and Computers in Simulation	(Dinçer & Yüksel, 2019)	Using FANP coping with inner dependency of the factors, using FTOPSIS and FVIKOR as common-used and coherent methods, and using Monte Carlo to be able to consider a high number of expert opinions.	Combined method based on of fuzzy TOPSIS, fuzzy ANP,, fuzzy VIKOR, and Monte Carlo Simulation	Service evaluation in banking sector
Journal of Purchasing and Supply Management	(Jolai et al., 2011)	Using a systematic method for their concept using TOPSIS for its main advantages (simplicity, straightforward process, etc.) together with GP.	Integration of multi-period goal programming and fuzzy TOPSIS	Purchasing from suppliers
	(Singh, 2014)	Coping with the subjective estimates related to the linguistic variables by using flexible fuzzy TOPSIS handling intangible together with tangible attributes and integrating it with MILP to optimize the decision.	Hybrid method including fuzzy TOPSIS and MILP	Allocating the demands of customers

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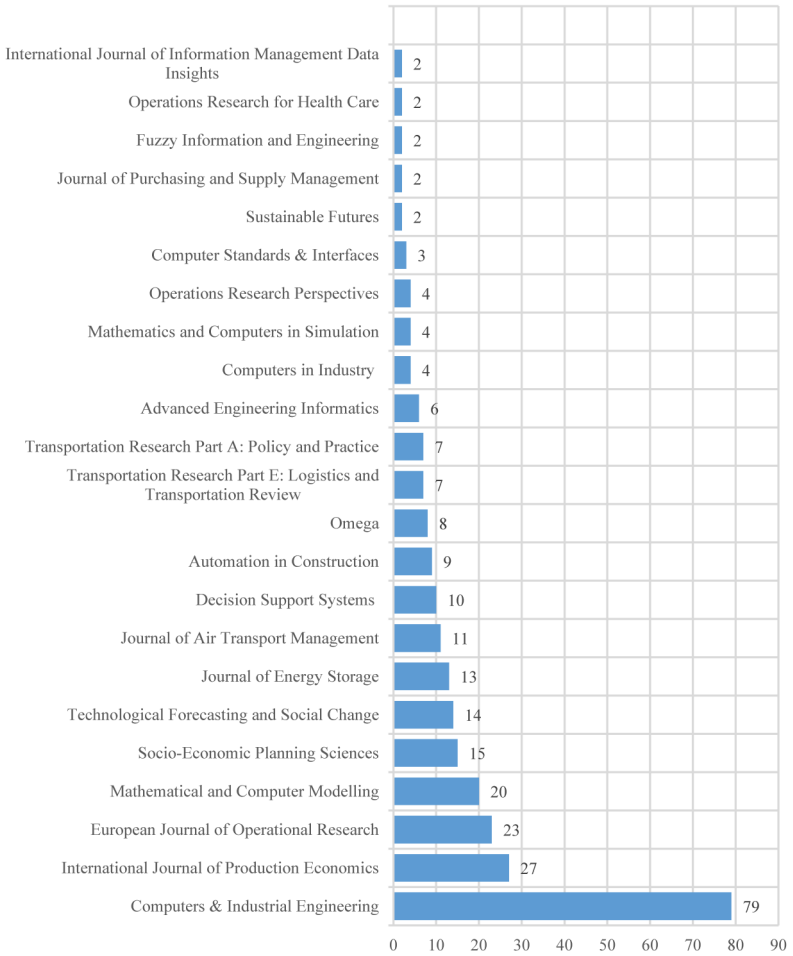
Table 5. Continued

Journal	Reference	Description	Method	Concept
Operations Research for Health Care	(Ahmed & Ali, 2020)	Using fuzzy TOPSIS linguistics for its simplicity.	Fuzzy TOPSIS with MILP model	Room scheduling
Sustainable Futures	(Oroojeni Mohammad Javad et al., 2020)	Integrating BWM for its less comparison data requirement together with more reliable and consistent results with TOPSIS as a widely used method.	Integration of BWM and fuzzy TOPSIS	Selecting green supplier selection in steel industries

Figure 2. Number of initially selected articles



this method were reviewed, and main advantages and disadvantages were analyzed. Then, the process of TOPSIS was described simply. In the final section, a comprehensive literature review conducted in decision support research area. The results show the applicability of TOPSIS based method in

Figure 3. Types of the methods used in some of the publication titles

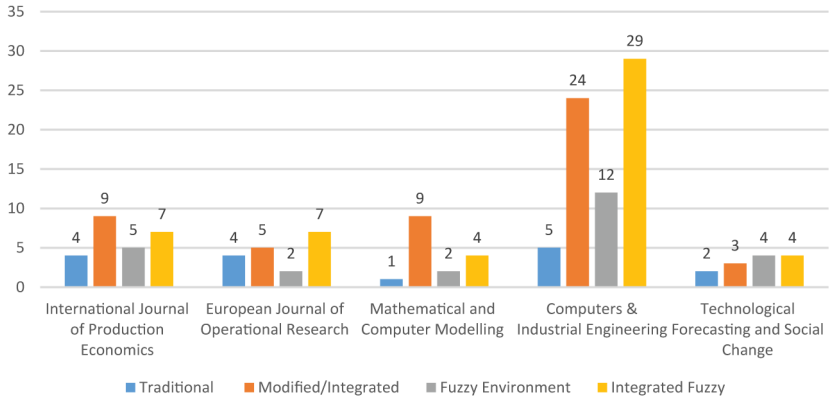
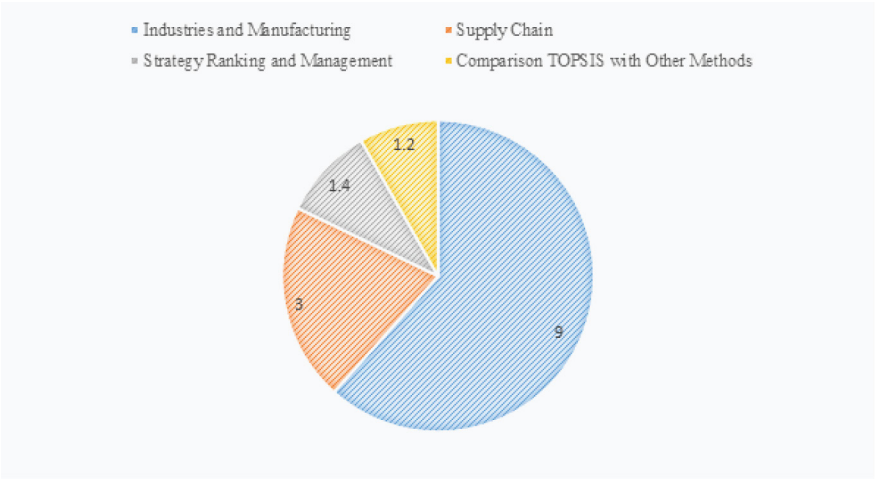


Figure 4. Distribution of articles using traditional TOPSIS



manifold area of specialization. For example, this method is applied in decision making problems in different industries (education, healthcare, financial and banking, etc.), supply chain, management, and strategy ranking, and so on.

Also, it can be shown that to address the limits and demerits of traditional TOPSIS, most of the articles applied modified and integrated methods. Application of fuzzy theories in different decision-making methods can also be mentioned based on the articles reviewed in this paper. The results provided in Table 2-5 can help researchers to gain an overview about the possible framework for using TOPSIS-based methods in different sectors and concepts. In this study, 240 papers were finalized to be used in the literature review section. It was shown that the majority of studies used modified/integrated and fuzzy integrated methods. Furthermore, most of integrated systems used AHP/fuzzy AHP method with TOPSIS based on the results of review.

Figure 5. Distribution of articles using modified/integrated TOPSIS

Figure 6. Distribution of articles using fuzzy-based TOPSIS

CONFLICTS OF INTEREST

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Figure 7. Distribution of articles using integrated fuzzy TOPSIS

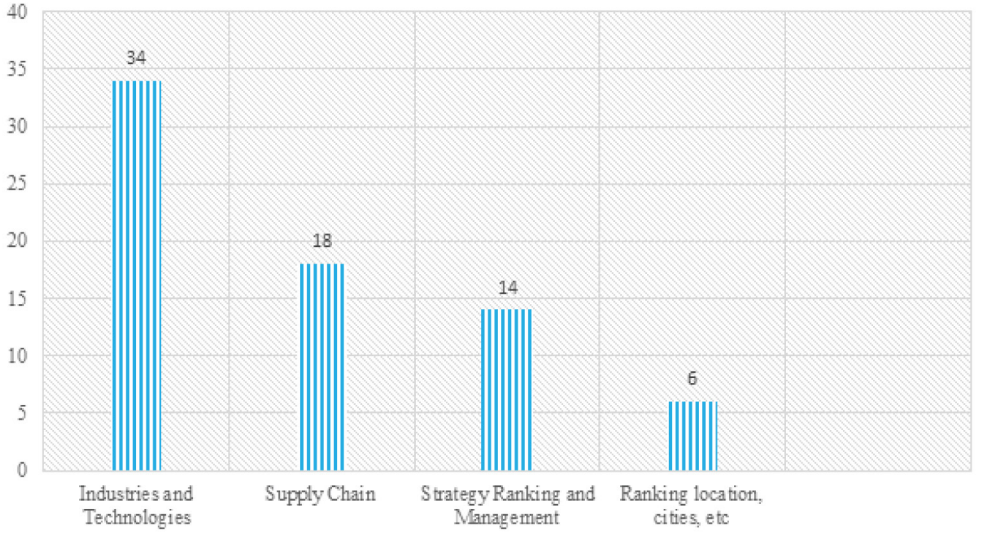

Figure 8. Common MCDM methods used in integrated TOPSIS

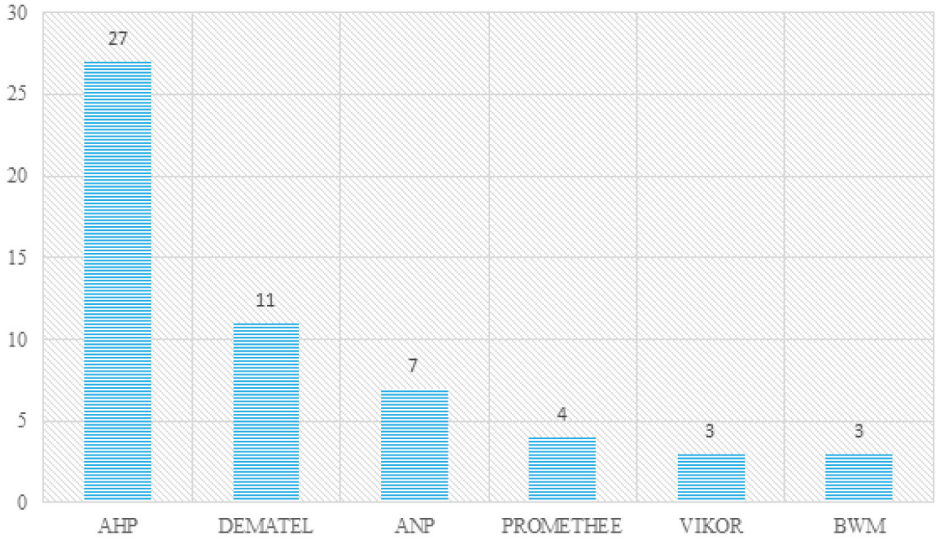

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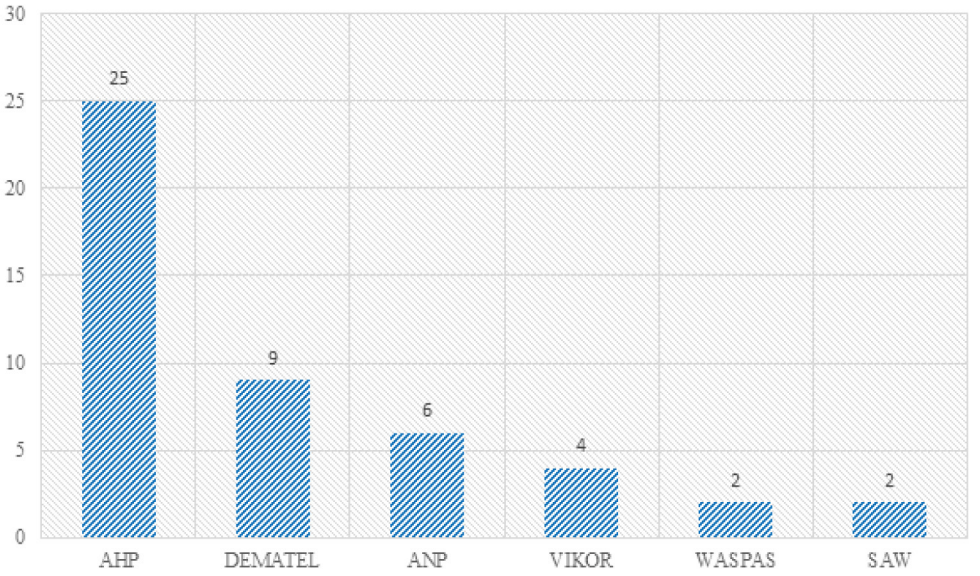
Figure 9. Common MCDM methods used in integrated fuzzy TOPSIS



REFERENCES

Ahmad, A. A., Sirjani, R., & Daneshvar, S. (2020). New hybrid probabilistic optimisation algorithm for optimal allocation of energy storage systems considering correlated wind farms. *Journal of Energy Storage*, *29*, 101335. 10.1016/j.est.2020.101335

Ahmad, F., Alnowibet, K. A., Alrasheedi, A. F., & Adhami, A. Y. (2022). A multi-objective model for optimizing the socio-economic performance of a pharmaceutical supply chain. *Socio-Economic Planning Sciences*, *79*, 101126. 10.1016/j.seps.2021.101126

Ahmed, A., & Ali, H. (2020). Modeling patient preference in an operating room scheduling problem. *Operations Research for Health Care*, *25*, 100257. 10.1016/j.orhc.2020.100257

Akgün, İ., & Erdal, H. (2019). Solving an ammunition distribution network design problem using multi-objective mathematical modeling, combined AHP-TOPSIS, and GIS. *Computers & Industrial Engineering*, *129*, 512–528. 10.1016/j.cie.2019.02.004

Aktar, M. S., De, M., Mazumder, S. K., & Maiti, M. (2021). Multi-Objective Green 4-dimensional transportation problems for breakable incompatible items with different fixed charge payment policies. *Computers & Industrial Engineering*, *156*, 107184. 10.1016/j.cie.2021.107184

Alamerew, Y. A., Kambanou, M. L., Sakao, T., & Brissaud, D. (2020). A multi-criteria evaluation method of product-level circularity strategies. *Sustainability (Basel)*, *12*(12), 5129. 10.3390/su12125129

Aljohani, K., & Thompson, R. G. (2020). A multi-criteria spatial evaluation framework to optimise the siting of freight consolidation facilities in inner-city areas. *Transportation Research Part A, Policy and Practice*, *138*, 51–69. 10.1016/j.tra.2020.05.020

Almomani, M. A., Aladeemy, M., Abdelhadi, A., & Mumani, A. (2013). A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques. *Computers & Industrial Engineering*, *66*(2), 461–469. 10.1016/j.cie.2013.07.011

Aloini, D., Dulmin, R., Mininno, V., Pellegrini, L., & Farina, G. (2018). Technology assessment with IF-TOPSIS: An application in the advanced underwater system sector. *Technological Forecasting and Social Change*, *131*, 38–48. 10.1016/j.techfore.2017.07.010

Anilkumar, B., Maniyeri, R., & Anish, S. (2021). Optimum selection of phase change material for solar box cooker integrated with thermal energy storage unit using multi-criteria decision-making technique. *Journal of Energy Storage*, *40*, 102807. 10.1016/j.est.2021.102807

Awasthi, A., Chauhan, S. S., & Goyal, S. K. (2010). A fuzzy multicriteria approach for evaluating environmental performance of suppliers. *International Journal of Production Economics*, *126*(2), 370–378. 10.1016/j.ijpe.2010.04.029

Awasthi, A., Chauhan, S. S., & Goyal, S. K. (2011). A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. *Mathematical and Computer Modelling*, *53*(1-2), 98–109. 10.1016/j.mcm.2010.07.023

Awasthi, A., Chauhan, S. S., Omrani, H., & Panahi, A. (2011). A hybrid approach based on SERVQUAL and fuzzy TOPSIS for evaluating transportation service quality. *Computers & Industrial Engineering*, *61*(3), 637–646. 10.1016/j.cie.2011.04.019

Awasthi, A., Omrani, H., & Gerber, P. (2018). Investigating ideal-solution based multicriteria decision making techniques for sustainability evaluation of urban mobility projects. *Transportation Research Part A, Policy and Practice*, *116*, 247–259. 10.1016/j.tra.2018.06.007

Ayağ, Z., & Özdemir, R. G. (2012). Evaluating machine tool alternatives through modified TOPSIS and alpha-cut based fuzzy ANP. *International Journal of Production Economics*, *140*(2), 630–636. 10.1016/j.ijpe.2012.02.009

Barak, S., & Dahooei, J. H. (2018). A novel hybrid fuzzy DEA-Fuzzy MADM method for airlines safety evaluation. *Journal of Air Transport Management*, *73*, 134–149. 10.1016/j.jairtraman.2018.09.001

Barros, C. P., & Wanke, P. (2015). An analysis of African airlines efficiency with two-stage TOPSIS and neural networks. *Journal of Air Transport Management*, *44*, 90–102. 10.1016/j.jairtraman.2015.03.002

Bilbao-Terol, A., Arenas-Parra, M., Cañal-Fernández, V., & Antomil-Ibias, J. (2014). Using TOPSIS for assessing the sustainability of government bond funds. *Omega*, *49*, 1–17. 10.1016/j.omega.2014.04.005

Bongo, M. F., & Ocampo, L. A. (2017). A hybrid fuzzy MCDM approach for mitigating airport congestion: A case in Ninoy Aquino International Airport. *Journal of Air Transport Management*, *63*, 1–16. 10.1016/j.jairtraman.2017.05.004

Bostancı, B., & Erdem, N. (2020). Investigating the satisfaction of citizens in municipality services using fuzzy modelling. *Socio-Economic Planning Sciences*, *69*, 100754. 10.1016/j.seps.2019.100754

Bulut, M., & Özcan, E. (2021a). Integration of battery energy storage systems into natural gas combined cycle power plants in fuzzy environment. *Journal of Energy Storage*, *36*, 102376. 10.1016/j.est.2021.102376

Bulut, M., & Özcan, E. (2021b). A novel approach towards evaluation of joint technology performances of battery energy storage system in a fuzzy environment. *Journal of Energy Storage*, *36*, 102361. 10.1016/j.est.2021.102361

Büyüközkan, G., Feyzioğlu, O., & Nebol, E. (2008). Selection of the strategic alliance partner in logistics value chain. *International Journal of Production Economics*, *113*(1), 148–158. 10.1016/j.ijpe.2007.01.016

Büyüközkan, G., & Güleryüz, S. (2016). A new integrated intuitionistic fuzzy group decision making approach for product development partner selection. *Computers & Industrial Engineering*, *102*, 383–395. 10.1016/j.cie.2016.05.038

Cao, X., & Lam, J. S. L. (2019). A fast reaction-based port vulnerability assessment: Case of Tianjin Port explosion. *Transportation Research Part A, Policy and Practice*, *128*, 11–33. 10.1016/j.tra.2019.05.019

Carayannis, E. G., Goletsis, Y., & Grigoroudis, E. (2018). Composite innovation metrics: MCDA and the Quadruple Innovation Helix framework. *Technological Forecasting and Social Change*, *131*, 4–17. 10.1016/j.techfore.2017.03.008

Cavallaro, F., Zavadskas, E. K., Streimikiene, D., & Mardani, A. (2019). Assessment of concentrated solar power (CSP) technologies based on a modified intuitionistic fuzzy topsis and trigonometric entropy weights. *Technological Forecasting and Social Change*, *140*, 258–270. 10.1016/j.techfore.2018.12.009

Celik, E., Bilisik, O. N., Erdogan, M., Gumus, A. T., & Baracli, H. (2013). An integrated novel interval type-2 fuzzy MCDM method to improve customer satisfaction in public transportation for Istanbul. *Transportation Research Part E, Logistics and Transportation Review*, *58*, 28–51. 10.1016/j.tre.2013.06.006

Chalgham, M., Khatrouch, I., Masmoudi, M., Walha, O. C., & Dammak, A. (2019). Inpatient admission management using multiple criteria decision-making methods. *Operations Research for Health Care*, *23*, 100173. 10.1016/j.orhc.2018.10.001

Chalvatzis, K. J., Malekpoor, H., Mishra, N., Lettice, F., & Choudhary, S. (2019). Sustainable resource allocation for power generation: The role of big data in enabling interindustry architectural innovation. *Technological Forecasting and Social Change*, *144*, 381–393. 10.1016/j.techfore.2018.04.031

Chang, C.-W., & Chen, C.-C. (2010). Development of expert decision model to monitor precision of solar silicon wafer machine line. *Computers & Industrial Engineering*, *59*(4), 481–487. 10.1016/j.cie.2010.05.008

Chen, C.-T., Lin, C.-T., & Huang, S.-F. (2006). A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics*, *102*(2), 289–301. 10.1016/j.ijpe.2005.03.009

Chen, H., Li, X.-Y., Lu, X.-R., Sheng, N., Zhou, W., Geng, H.-P., & Yu, S. (2021). A multi-objective optimization approach for the selection of overseas oil projects. *Computers & Industrial Engineering*, *151*, 106977. 10.1016/j.cie.2020.106977

Chen, J., Wu, Q., Zhang, L., & Wu, P. (2017). Multi-objective mean–variance–skewness model for nonconvex and stochastic optimal power flow considering wind power and load uncertainties. *European Journal of Operational Research*, *263*(2), 719–732. 10.1016/j.ejor.2017.06.018

Chen, M.-F., & Tzeng, G.-H. (2004). Combining grey relation and TOPSIS concepts for selecting an expatriate host country. *Mathematical and Computer Modelling*, *40*(13), 1473–1490. 10.1016/j.mcm.2005.01.006

Chen, S., Leng, Y., Mao, B., & Liu, S. (2014). Integrated weight-based multi-criteria evaluation on transfer in large transport terminals: A case study of the Beijing South Railway Station. *Transportation Research Part A, Policy and Practice*, *66*, 13–26. 10.1016/j.tra.2014.04.015

Chen, T.-Y. (2015). An interval type-2 fuzzy technique for order preference by similarity to ideal solutions using a likelihood-based comparison approach for multiple criteria decision analysis. *Computers & Industrial Engineering*, *85*, 57–72. 10.1016/j.cie.2015.03.005

Chen, Y., Kilgour, D. M., & Hipel, K. W. (2011). An extreme-distance approach to multiple criteria ranking. *Mathematical and Computer Modelling*, *53*(5-6), 646–658. 10.1016/j.mcm.2010.10.001

Chen, Z., & Yang, W. (2011). An MAGDM based on constrained FAHP and FTOPSIS and its application to supplier selection. *Mathematical and Computer Modelling*, *54*(11-12), 2802–2815. 10.1016/j.mcm.2011.06.068

chen, C., Xu, X., Zou, B., Peng, H., & Li, Z. (2021). Optimal decision of multiobjective and multiperiod anticipatory shipping under uncertain demand: A data-driven framework. *Computers & Industrial Engineering, 159*, 107445.

Choudhary, D., Qaiser, F. H., Choudhary, A., & Fernandes, K. (2022). A decision-making model for managing returns in a circular economy: A case of indian electronics industry. *International Journal of Production Economics*, ●●●, 108505. 10.1016/j.ijpe.2022.108505

Conejero, J. M., Preciado, J. C., Prieto, A. E., Bas, M., & Bolós, V. J. (2021). Applying data driven decision making to rank vocational and educational training programs with TOPSIS. *Decision Support Systems*, *142*, 113470. 10.1016/j.dss.2020.113470

Dahooie, J. H., Qorbani, A. R., & Daim, T. (2021). Providing a framework for selecting the appropriate method of technology acquisition considering uncertainty in hierarchical group decision-making: Case Study: Interactive television technology. *Technological Forecasting and Social Change*, *168*, 120760. 10.1016/j.techfore.2021.120760

Darestani, S. A., & Hemmati, M. (2019). Robust optimization of a bi-objective closed-loop supply chain network for perishable goods considering queue system. *Computers & Industrial Engineering*, *136*, 277–292. 10.1016/j.cie.2019.07.018

de Farias Aires, R. F., & Ferreira, L. (2019). A new approach to avoid rank reversal cases in the TOPSIS method. *Computers & Industrial Engineering*, *132*, 84–97. 10.1016/j.cie.2019.04.023

de Lima Silva, D. F., & de Almeida Filho, A. T. (2020). Sorting with TOPSIS through boundary and characteristic profiles. *Computers & Industrial Engineering*, *141*, 106328. 10.1016/j.cie.2020.106328

Deepu, T., & Ravi, V. (2021). Supply chain digitalization: An integrated MCDM approach for inter-organizational information systems selection in an electronic supply chain. *International Journal of Information Management Data Insights*, *1*(2), 100038. 10.1016/j.jjimei.2021.100038

Dev, N. K., Shankar, R., Gupta, R., & Dong, J. (2019). Multi-criteria evaluation of real-time key performance indicators of supply chain with consideration of big data architecture. *Computers & Industrial Engineering*, *128*, 1076–1087. 10.1016/j.cie.2018.04.012

Deveci, M., Demirel, N. Ç., & Ahmetoğlu, E. (2017). Airline new route selection based on interval type-2 fuzzy MCDM: A case study of new route between Turkey-North American region destinations. *Journal of Air Transport Management*, *59*, 83–99. 10.1016/j.jairtraman.2016.11.013

Dincer, H., Hacioglu, U., Tatoglu, E., & Delen, D. (2016). A fuzzy-hybrid analytic model to assess investors' perceptions for industry selection. *Decision Support Systems*, *86*, 24–34. 10.1016/j.dss.2016.03.005

Dinçer, H., & Yüksel, S. (2019). An integrated stochastic fuzzy MCDM approach to the balanced scorecard-based service evaluation. *Mathematics and Computers in Simulation*, *166*, 93–112. 10.1016/j.matcom.2019.04.008

Divya, C., Raju, L. S., & Singaravel, B. (2020). A Review of TOPSIS method for multi criteria optimization in manufacturing environment. Intelligent Techniques and Applications in Science and Technology: Proceedings of the First International Conference on Innovations in Modern Science and Technology 1 10.1007/978-3-030-42363-6_84

Dong, Y., Tan, R., Zhang, P., Peng, Q., & Shao, P. (2021). Product redesign using functional backtrack with digital twin. *Advanced Engineering Informatics*, *49*, 101361. 10.1016/j.aei.2021.101361

Du, J., Liu, S., & Liu, Y. (2021). A novel grey multi-criteria three-way decisions model and its application. *Computers & Industrial Engineering*, *158*, 107405. 10.1016/j.cie.2021.107405

Elibal, K., & Özceylan, E. (2022). Comparing industry 4.0 maturity models in the perspective of TQM principles using Fuzzy MCDM methods. *Technological Forecasting and Social Change*, *175*, 121379. 10.1016/j.techfore.2021.121379

Essaadi, I., Grabot, B., & Féniès, P. (2019). Location of global logistic hubs within Africa based on a fuzzy multi-criteria approach. *Computers & Industrial Engineering*, *132*, 1–22. 10.1016/j.cie.2019.03.046

Faghih-Roohi, S., Akcay, A., Zhang, Y., Shekarian, E., & de Jong, E. (2020). A group risk assessment approach for the selection of pharmaceutical product shipping lanes. *International Journal of Production Economics*, *229*, 107774. 10.1016/j.ijpe.2020.107774

Faghiri, S., Aria, H. P., & Shafii, M. B. (2022). Multi-objective optimization of acetone droplet impingement on phase change material in direct-contact discharge method. *Journal of Energy Storage*, *46*, 103862. 10.1016/j.est.2021.103862

Feng, C.-M., & Wang, R.-T. (2000). Performance evaluation for airlines including the consideration of financial ratios. *Journal of Air Transport Management*, *6*(3), 133–142. 10.1016/S0969-6997(00)00003-X

Ferjani, A., Ammar, A., Pierreval, H., & Elkosantini, S. (2017). A simulation-optimization based heuristic for the online assignment of multi-skilled workers subjected to fatigue in manufacturing systems. *Computers & Industrial Engineering*, *112*, 663–674. 10.1016/j.cie.2017.02.008

Gallego-Ayala, J. (2012). Selecting irrigation water pricing alternatives using a multi-methodological approach. *Mathematical and Computer Modelling*, *55*(3-4), 861–883. 10.1016/j.mcm.2011.09.014

Gamberini, R., Grassi, A., & Rimini, B. (2006). A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem. *International Journal of Production Economics*, *102*(2), 226–243. 10.1016/j.ijpe.2005.02.013

García-Cascales, M. S., & Lamata, M. T. (2012). On rank reversal and TOPSIS method. *Mathematical and Computer Modelling*, *56*(5-6), 123–132. 10.1016/j.mcm.2011.12.022

Garg, C. P. (2016). A robust hybrid decision model for evaluation and selection of the strategic alliance partner in the airline industry. *Journal of Air Transport Management*, *52*, 55–66. 10.1016/j.jairtraman.2015.12.009

Garg, D., Sidhu, J., & Rani, S. (2019). Improved TOPSIS: A multi-criteria decision making for research productivity in cloud security. *Computer Standards & Interfaces*, *65*, 61–78. 10.1016/j.csi.2019.02.002

Ghorabaee, M. K., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2017). A new hybrid simulation-based assignment approach for evaluating airlines with multiple service quality criteria. *Journal of Air Transport Management*, *63*, 45–60. 10.1016/j.jairtraman.2017.05.008

Goswami, S. S., & Behera, D. K. (2021). An analysis for selecting best smartphone model by AHP-TOPSIS decision-making methodology. [IJSSMET]. *International Journal of Service Science, Management, Engineering, and Technology*, *12*(3), 116–137. 10.4018/IJSSMET.2021050107

Gul, M., & Yucesan, M. (2022). Performance evaluation of Turkish Universities by an integrated Bayesian BWM-TOPSIS model. *Socio-Economic Planning Sciences*, *80*, 101173. 10.1016/j.seps.2021.101173

Guo, J., Du, Q., & He, Z. (2021). A method to improve the resilience of multimodal transport network: Location selection strategy of emergency rescue facilities. *Computers & Industrial Engineering*, *161*, 107678. 10.1016/j.cie.2021.107678

Gupta, R., Rathore, B., Srivastava, A., & Biswas, B. (2022). Decision-Making Framework for Identifying Regions Vulnerable to Transmission of COVID-19 Pandemic. *Computers & Industrial Engineering*, *169*, 108207. 10.1016/j.cie.2022.10820735529174

Gupta, S., Soni, U., & Kumar, G. (2019). Green supplier selection using multi-criterion decision making under fuzzy environment: A case study in automotive industry. *Computers & Industrial Engineering*, *136*, 663–680. 10.1016/j.cie.2019.07.038

Hacioglu, U., Chlyeh, D., Yilmaz, M. K., Tatoglu, E., & Delen, D. (2021). Crafting performance-based cryptocurrency mining strategies using a hybrid analytics approach. *Decision Support Systems*, *142*, 113473. 10.1016/j.dss.2020.113473

Hamdan, S., & Cheaitou, A. (2017). Dynamic green supplier selection and order allocation with quantity discounts and varying supplier availability. *Computers & Industrial Engineering*, *110*, 573–589. 10.1016/j.cie.2017.03.028

Huang, W., Shuai, B., Sun, Y., Wang, Y., & Antwi, E. (2018). Using entropy-TOPSIS method to evaluate urban rail transit system operation performance: The China case. *Transportation Research Part A, Policy and Practice*, *111*, 292–303. 10.1016/j.tra.2018.03.025

Hujainah, F., Bakar, R. B. A., & Abdulgabber, M. A. (2019). StakeQP: A semi-automated stakeholder quantification and prioritisation technique for requirement selection in software system projects. *Decision Support Systems*, *121*, 94–108. 10.1016/j.dss.2019.04.009

Intepe, G., Bozdag, E., & Koc, T. (2013). The selection of technology forecasting method using a multi-criteria interval-valued intuitionistic fuzzy group decision making approach. *Computers & Industrial Engineering*, *65*(2), 277–285. 10.1016/j.cie.2013.03.002

Irfan, M., Elavarasan, R. M., Ahmad, M., Mohsin, M., Dagar, V., & Hao, Y. (2022). Prioritizing and overcoming biomass energy barriers: Application of AHP and G-TOPSIS approaches. *Technological Forecasting and Social Change*, *177*, 121524. 10.1016/j.techfore.2022.121524

Işıklar, G., & Büyüközkan, G. (2007). Using a multi-criteria decision making approach to evaluate mobile phone alternatives. *Computer Standards & Interfaces*, *29*(2), 265–274. 10.1016/j.csi.2006.05.002

Jahanshahloo, G. R., Khodabakhshi, M., Lotfi, F. H., & Goudarzi, M. M. (2011). A cross-efficiency model based on super-efficiency for ranking units through the TOPSIS approach and its extension to the interval case. *Mathematical and Computer Modelling*, *53*(9-10), 1946–1955. 10.1016/j.mcm.2011.01.025

Jahanshahloo, G. R., Lotfi, F. H., & Davoodi, A. (2009). Extension of TOPSIS for decision-making problems with interval data: Interval efficiency. *Mathematical and Computer Modelling*, *49*(5-6), 1137–1142. 10.1016/j.mcm.2008.07.009

Jalayer, M., Azheian, M., & Kermani, M. A. M. A. (2018). A hybrid algorithm based on community detection and multi attribute decision making for influence maximization. *Computers & Industrial Engineering*, *120*, 234–250. 10.1016/j.cie.2018.04.049

Jani, V., & Abdi, H. (2018). Optimal allocation of energy storage systems considering wind power uncertainty. *Journal of Energy Storage*, *20*, 244–253. 10.1016/j.est.2018.09.017

Jiang, Y.-P., Liang, H.-M., & Sun, M. (2015). A method for discrete stochastic MADM problems based on the ideal and nadir solutions. *Computers & Industrial Engineering*, *87*, 114–125. 10.1016/j.cie.2015.04.019

Jolai, F., Yazdian, S. A., Shahanaghi, K., & Khojasteh, M. A. (2011). Integrating fuzzy TOPSIS and multi-period goal programming for purchasing multiple products from multiple suppliers. *Journal of Purchasing and Supply Management*, *17*(1), 42–53. 10.1016/j.pursup.2010.06.004

Joshi, D., & Kumar, S. (2016). Interval-valued intuitionistic hesitant fuzzy Choquet integral based TOPSIS method for multi-criteria group decision making. *European Journal of Operational Research*, *248*(1), 183–191. 10.1016/j.ejor.2015.06.047

Kahraman, C., Çevik, S., Ates, N. Y., & Gülbay, M. (2007). Fuzzy multi-criteria evaluation of industrial robotic systems. *Computers & Industrial Engineering*, *52*(4), 414–433. 10.1016/j.cie.2007.01.005

Kandakoglu, A., Celik, M., & Akgun, I. (2009). A multi-methodological approach for shipping registry selection in maritime transportation industry. *Mathematical and Computer Modelling*, *49*(3-4), 586–597. 10.1016/j.mcm.2008.09.001

Kannan, D., de Sousa Jabbour, A. B. L., & Jabbour, C. J. C. (2014). Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of Operational Research*, *233*(2), 432–447. 10.1016/j.ejor.2013.07.023

Kao, H.-P., Wang, B., Dong, J., & Ku, K.-C. (2006). An event-driven approach with makespan/cost tradeoff analysis for project portfolio scheduling. *Computers in Industry*, *57*(5), 379–397. 10.1016/j.compind.2005.11.004

Kapoor, N., Ahmad, N., Nayak, S. K., Singh, S. P., Ilavarasan, P. V., & Ramamoorthy, P. (2021). Identifying infrastructural gap areas for smart and sustainable tribal village development: A data science approach from India. *International Journal of Information Management Data Insights*, *1*(2), 100041. 10.1016/j.jjimei.2021.100041

Karasan, A., Erdogan, M., & Cinar, M. (2022). Healthcare service quality evaluation: An integrated decision-making methodology and a case study. *Socio-Economic Planning Sciences*, *82*, 101234. 10.1016/j.seps.2022.101234

Karimi, H., Jadid, S., & Makui, A. (2021). Stochastic energy scheduling of multi-microgrid systems considering independence performance index and energy storage systems. *Journal of Energy Storage*, *33*, 102083. 10.1016/j.est.2020.102083

Karimi-Nasab, M., & Seyedhoseini, S. (2013). Multi-level lot sizing and job shop scheduling with compressible process times: A cutting plane approach. *European Journal of Operational Research*, *231*(3), 598–616. 10.1016/j.ejor.2013.06.021

Kaur, H., & Singh, S. P. (2021). Multi-stage hybrid model for supplier selection and order allocation considering disruption risks and disruptive technologies. *International Journal of Production Economics*, *231*, 107830. 10.1016/j.ijpe.2020.107830

Keramatpour, M., Niaki, S. T. A., & Pasandideh, S. H. R. (2018). A bi-objective two-level newsvendor problem with discount policies and budget constraint. *Computers & Industrial Engineering*, *120*, 192–205. 10.1016/j.cie.2018.04.040

Khalili-Damghani, K., & Sadi-Nezhad, S. (2013). A decision support system for fuzzy multi-objective multi-period sustainable project selection. *Computers & Industrial Engineering*, *64*(4), 1045–1060. 10.1016/j.cie.2013.01.016

Khoshsirat, M., Dabbagh, R., & Bozorgi-Amiri, A. (2021). A multi-objective robust possibilistic programming approach to coordinating procurement operations in the disaster supply chain using a multi-attribute reverse auction mechanism. *Computers & Industrial Engineering*, *158*, 107414. 10.1016/j.cie.2021.107414

Khosroshahi, H., Azad, N., Jabbarzadeh, A., & Verma, M. (2021). Investigating the level and quality of the information in the environmental disclosure report of a corporation considering government intervention. *International Journal of Production Economics*, *235*, 108071. 10.1016/j.ijpe.2021.108071

Kilic, H. S., & Yalcin, A. S. (2021). Comparison of municipalities considering environmental sustainability via neutrosophic DEMATEL based TOPSIS. *Socio-Economic Planning Sciences*, *75*, 100827. 10.1016/j.seps.2020.100827

Kilic, H. S., Zaim, S., & Delen, D. (2014). Development of a hybrid methodology for ERP system selection: The case of Turkish Airlines. *Decision Support Systems*, *66*, 82–92. 10.1016/j.dss.2014.06.011

Kim, G., Park, C. S., & Yoon, K. P. (1997). Identifying investment opportunities for advanced manufacturing systems with comparative-integrated performance measurement. *International Journal of Production Economics*, *50*(1), 23–33. 10.1016/S0925-5273(97)00014-5

Kiracı, K., & Akan, E. (2020). Aircraft selection by applying AHP and TOPSIS in interval type-2 fuzzy sets. *Journal of Air Transport Management*, *89*, 101924. 10.1016/j.jairtraman.2020.10192432989347

Kucukvar, M., Gumus, S., Egilmez, G., & Tatari, O. (2014). Ranking the sustainability performance of pavements: An intuitionistic fuzzy decision making method. *Automation in Construction*, *40*, 33–43. 10.1016/j.autcon.2013.12.009

Kuo, M.-S., & Liang, G.-S. (2011). A novel hybrid decision-making model for selecting locations in a fuzzy environment. *Mathematical and Computer Modelling*, *54*(1-2), 88–104. 10.1016/j.mcm.2011.01.038

Kuo, M.-S., Tzeng, G.-H., & Huang, W.-C. (2007). Group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment. *Mathematical and Computer Modelling*, *45*(3-4), 324–339. 10.1016/j.mcm.2006.05.006

Kuo, T. (2017). A modified TOPSIS with a different ranking index. *European Journal of Operational Research*, *260*(1), 152–160. 10.1016/j.ejor.2016.11.052

Kuo, Y., Yang, T., Cho, C., & Tseng, Y.-C. (2008). Using simulation and multi-criteria methods to provide robust solutions to dispatching problems in a flow shop with multiple processors. *Mathematics and Computers in Simulation*, *78*(1), 40–56. 10.1016/j.matcom.2007.06.002

Kwok, P. K., & Lau, H. Y. (2019). Hotel selection using a modified TOPSIS-based decision support algorithm. *Decision Support Systems*, *120*, 95–105. 10.1016/j.dss.2019.02.004

Lai, Y.-J., Liu, T.-Y., & Hwang, C.-L. (1994). Topsis for MODM. *European Journal of Operational Research*, *76*(3), 486–500. 10.1016/0377-2217(94)90282-8

Lee, Y., Hu, J., & Lim, M. K. (2021). Maximising the circular economy and sustainability outcomes: An end-of-life tyre recycling outlets selection model. *International Journal of Production Economics*, *232*, 107965. 10.1016/j.ijpe.2020.107965

Li, D., Zhao, L., Wang, C., Sun, W., & Xue, J. (2018). Selection of China's imported grain distribution centers in the context of the Belt and Road initiative. *Transportation Research Part E, Logistics and Transportation Review*, *120*, 16–34. 10.1016/j.tre.2018.10.007

Li, H.-L. (1987). Solving discrete multicriteria decision problems based on logic-based decision support systems. *Decision Support Systems*, *3*(2), 101–119. 10.1016/0167-9236(87)90070-4

Li, M., Porter, A. L., Suominen, A., Burmaoglu, S., & Carley, S. (2021). An exploratory perspective to measure the emergence degree for a specific technology based on the philosophy of swarm intelligence. *Technological Forecasting and Social Change*, *166*, 120621. 10.1016/j.techfore.2021.120621

Li, S., & Wei, C. (2020). A large scale group decision making approach in healthcare service based on sub-group weighting model and hesitant fuzzy linguistic information. *Computers & Industrial Engineering*, *144*, 106444. 10.1016/j.cie.2020.106444

Li, S.-T., & Chou, W.-C. (2014). Power planning in ICT infrastructure: A multi-criteria operational performance evaluation approach. *Omega*, *49*, 134–148. 10.1016/j.omega.2014.05.006

Li, Y.-M., & Lai, C.-Y. (2014). A social appraisal mechanism for online purchase decision support in the micro-blogosphere. *Decision Support Systems*, *59*, 190–205. 10.1016/j.dss.2013.11.007

Li, Z., Xu, J., Lev, B., & Gang, J. (2015). Multi-criteria group individual research output evaluation based on context-free grammar judgments with assessing attitude. *Omega*, *57*, 282–293. 10.1016/j.omega.2015.09.001

Li, Z., Zhang, Q., & Liao, H. (2019). Efficient-equitable-ecological evaluation of regional water resource coordination considering both visible and virtual water. *Omega*, *83*, 223–235. 10.1016/j.omega.2018.06.003

Lima-Junior, F. R., & Carpinetti, L. C. R. (2016). Combining SCOR® model and fuzzy TOPSIS for supplier evaluation and management. *International Journal of Production Economics*, *174*, 128–141. 10.1016/j.ijpe.2016.01.023

Lin, H.-T., & Chang, W.-L. (2008). Order selection and pricing methods using flexible quantity and fuzzy approach for buyer evaluation. *European Journal of Operational Research*, *187*(2), 415–428. 10.1016/j.ejor.2007.03.003

Lin, L., Xia, Y., & Wu, D. (2020). A hybrid fuzzy multiple criteria decision-making approach for comprehensive performance evaluation of tunnel boring machine disc cutter. *Computers & Industrial Engineering*, *149*, 106793. 10.1016/j.cie.2020.106793

Lin, M.-C., Wang, C.-C., Chen, M.-S., & Chang, C. A. (2008). Using AHP and TOPSIS approaches in customer-driven product design process. *Computers in Industry*, *59*(1), 17–31. 10.1016/j.compind.2007.05.013

Lin, S.-S., Shen, S.-L., Zhou, A., & Zhang, N. (2021). Ensemble model for risk status evaluation of excavation. *Automation in Construction*, *132*, 103943. 10.1016/j.autcon.2021.103943

Lin, S.-S., Zhang, N., Zhou, A., & Shen, S.-L. (2022). Risk evaluation of excavation based on fuzzy decision-making model. *Automation in Construction*, *136*, 104143. 10.1016/j.autcon.2022.104143

Lin, Y.-H., Lee, P.-C., Chang, T.-P., & Ting, H.-I. (2008). Multi-attribute group decision making model under the condition of uncertain information. *Automation in Construction*, *17*(6), 792–797. 10.1016/j.autcon.2008.02.011

Lin, Y.-K., & Yeh, C.-T. (2012). Multi-objective optimization for stochastic computer networks using NSGA-II and TOPSIS. *European Journal of Operational Research*, *218*(3), 735–746. 10.1016/j.ejor.2011.11.028

Liu, D., & Wang, L. (2019). Multi-attribute decision making with hesitant fuzzy information based on least common multiple principle and reference ideal method. *Computers & Industrial Engineering*, *137*, 106021. 10.1016/j.cie.2019.106021

Liu, E., Wang, Y., Chen, W., Chen, W., & Ning, S. (2021). Evaluating the transformation of China's resource-based cities: An integrated sequential weight and TOPSIS approach. *Socio-Economic Planning Sciences*, *77*, 101022. 10.1016/j.seps.2021.101022

Liu, Y., Eckert, C., Yannou-Le Bris, G., & Petit, G. (2019). A fuzzy decision tool to evaluate the sustainable performance of suppliers in an agrifood value chain. *Computers & Industrial Engineering*, *127*, 196–212. 10.1016/j.cie.2018.12.022

Liu, Y., Sun, Z., Liang, H., & Dong, Y. (2021). Ranking range model in multiple attribute decision making: A comparison of selected methods. *Computers & Industrial Engineering*, *155*, 107180. 10.1016/j.cie.2021.107180

Liu, Z., Ming, X., Qiu, S., Qu, Y., & Zhang, X. (2020). A framework with hybrid approach to analyse system requirements of smart PSS toward customer needs and co-creative value propositions. *Computers & Industrial Engineering*, *139*, 105776. 10.1016/j.cie.2019.03.040

Lupo, T., & Bellomo, E. (2019). DINESERV along with fuzzy hierarchical TOPSIS to support the best practices observation and service quality improvement in the restaurant context. *Computers & Industrial Engineering*, *137*, 106046. 10.1016/j.cie.2019.106046

Ma, J., Harstvedt, J. D., Jaradat, R., & Smith, B. (2020). Sustainability driven multi-criteria project portfolio selection under uncertain decision-making environment. *Computers & Industrial Engineering*, *140*, 106236. 10.1016/j.cie.2019.106236

Maghsoudlou, H., Kahag, M. R., Niaki, S. T. A., & Pourvaziri, H. (2016). Bi-objective optimization of a three-echelon multi-server supply-chain problem in congested systems: Modeling and solution. *Computers & Industrial Engineering*, *99*, 41–62. 10.1016/j.cie.2016.07.008

Maleki, H., Ashrafi, M., Ilghani, N. Z., Goodarzi, M., & Muhammad, T. (2021). Pareto optimal design of a finned latent heat thermal energy storage unit using a novel hybrid technique. *Journal of Energy Storage*, *44*, 103310. 10.1016/j.est.2021.103310

Marchetti, D., & Wanke, P. (2020). Efficiency of the rail sections in Brazilian railway system, using TOPSIS and a genetic algorithm to analyse optimized scenarios. *Transportation Research Part E, Logistics and Transportation Review*, *135*, 101858. 10.1016/j.tre.2020.101858

Martín, J. C., Martín-Domingo, L., Lohmann, G., & Spasojevic, B. (2019). The role of travel patterns in airport duty-free shopping satisfaction: A case study from an Australian regional airport. *Journal of Air Transport Management*, *80*, 101691. 10.1016/j.jairtraman.2019.101691

Mela, K., Tiainen, T., & Heinisuo, M. (2012). Comparative study of multiple criteria decision making methods for building design. *Advanced Engineering Informatics*, *26*(4), 716–726. 10.1016/j.aei.2012.03.001

Meng, F., & Zhang, Q. (2014). Induced continuous Choquet integral operators and their application to group decision making. *Computers & Industrial Engineering*, *68*, 42–53. 10.1016/j.cie.2013.11.013

Micale, R., La Fata, C. M., & La Scalia, G. (2019). A combined interval-valued ELECTRE TRI and TOPSIS approach for solving the storage location assignment problem. *Computers & Industrial Engineering*, *135*, 199–210. 10.1016/j.cie.2019.06.011

Micale, R., Marannano, G., Giallanza, A., Miglietta, P., Agnusdei, G., & La Scalia, G. (2019). Sustainable vehicle routing based on firefly algorithm and TOPSIS methodology. *Sustainable Futures : An Applied Journal of Technology, Environment and Society*, *1*, 100001. 10.1016/j.sftr.2019.100001

Milani, A. S., Shanian, A., & El-Lahham, C. (2008). A decision-based approach for measuring human behavioral resistance to organizational change in strategic planning. *Mathematical and Computer Modelling*, *48*(11-12), 1765–1774. 10.1016/j.mcm.2008.06.018

Miranda-Ackerman, M. A., Azzaro-Pantel, C., & Aguilar-Lasserre, A. A. (2017). A green supply chain network design framework for the processed food industry: Application to the orange juice agrofood cluster. *Computers & Industrial Engineering*, *109*, 369–389. 10.1016/j.cie.2017.04.031

Mohammed, A., Harris, I., & Govindan, K. (2019). A hybrid MCDM-FMOO approach for sustainable supplier selection and order allocation. *International Journal of Production Economics*, *217*, 171–184. 10.1016/j.ijpe.2019.02.003

Mohammed, A., Harris, I., Soroka, A., & Nujoom, R. (2019). A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design. *Computers & Industrial Engineering*, *127*, 297–312. 10.1016/j.cie.2018.09.052

Mohammed, A., Naghshineh, B., Spiegler, V., & Carvalho, H. (2021). Conceptualising a supply and demand resilience methodology: A hybrid DEMATEL-TOPSIS-possibilistic multi-objective optimization approach. *Computers & Industrial Engineering*, *160*, 107589. 10.1016/j.cie.2021.107589

Mohanty, P. P., Mahapatra, S. S., Mohanty, A., & Sthitapragyan, . (2018). A novel multi-attribute decision making approach for selection of appropriate product conforming ergonomic considerations. *Operations Research Perspectives*, *5*, 82–93. 10.1016/j.orp.2018.01.004

Montanari, R., Micale, R., Bottani, E., Volpi, A., & La Scalia, G. (2021). Evaluation of routing policies using an interval-valued TOPSIS approach for the allocation rules. *Computers & Industrial Engineering*, *156*, 107256. 10.1016/j.cie.2021.107256

Mulliner, E., Malys, N., & Maliene, V. (2016). Comparative analysis of MCDM methods for the assessment of sustainable housing affordability. *Omega*, *59*, 146–156. 10.1016/j.omega.2015.05.013

Nicolalde, J. F., Cabrera, M., Martínez-Gómez, J., Salazar, R. B., & Reyes, E. (2022). Selection of a phase change material for energy storage by multi-criteria decision method regarding the thermal comfort in a vehicle. *Journal of Energy Storage*, *51*, 104437. 10.1016/j.est.2022.104437

Nieto-Morote, A., & Ruz-Vila, F. (2012). A fuzzy multi-criteria decision-making model for construction contractor prequalification. *Automation in Construction*, *25*, 8–19. 10.1016/j.autcon.2012.04.004

Nilashi, M., Samad, S., Manaf, A. A., Ahmadi, H., Rashid, T. A., Munshi, A., & Ahmed, O. H. (2019). Factors influencing medical tourism adoption in Malaysia: A DEMATEL-Fuzzy TOPSIS approach. *Computers & Industrial Engineering*, *137*, 106005. 10.1016/j.cie.2019.106005

Ning, X., Ding, L., Luo, H., & Qi, S. (2016). A multi-attribute model for construction site layout using intuitionistic fuzzy logic. *Automation in Construction*, *72*, 380–387. 10.1016/j.autcon.2016.09.008

Ning, X., Lam, K.-C., & Lam, M. C.-K. (2011). A decision-making system for construction site layout planning. *Automation in Construction*, *20*(4), 459–473. 10.1016/j.autcon.2010.11.014

Nojavan, M., Heidari, A., & Mohammaditabar, D. (2021). A fuzzy service quality based approach for performance evaluation of educational units. *Socio-Economic Planning Sciences*, *73*, 100816. 10.1016/j.seps.2020.100816

Ocampo, L., Alinsub, J., Casul, R. A., Enquig, G., Luar, M., Panuncillon, N., Bongo, M., & Ocampo, C. O. (2019). Public service quality evaluation with SERVQUAL and AHP-TOPSIS: A case of Philippine government agencies. *Socio-Economic Planning Sciences*, *68*, 100604. 10.1016/j.seps.2017.12.002

Oliveira, G. A., Tan, K. H., & Guedes, B. T. (2018). Lean and green approach: An evaluation tool for new product development focused on small and medium enterprises. *International Journal of Production Economics*, *205*, 62–73. 10.1016/j.ijpe.2018.08.026

Olson, D. L. (2004). Comparison of weights in TOPSIS models. *Mathematical and Computer Modelling*, *40*(7-8), 721–727. 10.1016/j.mcm.2004.10.003

Opricovic, S., & Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, *156*(2), 445–455. 10.1016/S0377-2217(03)00020-1

Orji, I. J., & Liu, S. (2020). A dynamic perspective on the key drivers of innovation-led lean approaches to achieve sustainability in manufacturing supply chain. *International Journal of Production Economics*, *219*, 480–496. 10.1016/j.ijpe.2018.12.002

Oroojeni Mohammad Javad, M., Darvishi, M., & Oroojeni Mohammad Javad, A. (2020). Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: A case study of Khouzestan steel company. *Sustainable Futures : An Applied Journal of Technology, Environment and Society*, *2*, 100012. 10.1016/j.sftr.2020.100012

Ouenniche, J., Pérez-Gladish, B., & Bouslah, K. (2018). An out-of-sample framework for TOPSIS-based classifiers with application in bankruptcy prediction. *Technological Forecasting and Social Change*, *131*, 111–116. 10.1016/j.techfore.2017.05.034

Özceylan, E., Çetinkaya, C., Erbaş, M., & Kabak, M. (2016). Logistic performance evaluation of provinces in Turkey: A GIS-based multi-criteria decision analysis. *Transportation Research Part A, Policy and Practice*, *94*, 323–337. 10.1016/j.tra.2016.09.020

Özceylan, E., Erbaş, M., Tolon, M., Kabak, M., & Durğut, T. (2016). Evaluation of freight villages: A GIS-based multi-criteria decision analysis. *Computers in Industry*, *76*, 38–52. 10.1016/j.compind.2015.12.003

Parkan, C., & Wu, M.-L. (1999). Decision-making and performance measurement models with applications to robot selection. *Computers & Industrial Engineering*, *36*(3), 503–523. 10.1016/S0360-8352(99)00146-1

Pätäri, E., Karell, V., Luukka, P., & Yeomans, J. S. (2018). Comparison of the multicriteria decision-making methods for equity portfolio selection: The US evidence. *European Journal of Operational Research*, *265*(2), 655–672. 10.1016/j.ejor.2017.08.001

Peng, Y., Kou, G., Wang, G., & Shi, Y. (2011). FAMCDM: A fusion approach of MCDM methods to rank multiclass classification algorithms. *Omega*, *39*(6), 677–689. 10.1016/j.omega.2011.01.009

Ping, Y.-J., Liu, R., Lin, W., & Liu, H.-C. (2020). A new integrated approach for engineering characteristic prioritization in quality function deployment. *Advanced Engineering Informatics*, *45*, 101099. 10.1016/j.aei.2020.101099

Rao, C.-J., Liu, J.-E., Dong, J.-H., & Jentsch, P. C. (2014). Hybrid multi-attribute decision making method of electric coal procurement in industry. *Fuzzy Information and Engineering*, *6*(4), 451–462. 10.1016/j.fiae.2015.01.004

Rehman, O. U., & Ali, Y. (2021). Optimality study of China's crude oil imports through China Pakistan economic corridor using fuzzy TOPSIS and Cost-Benefit analysis. *Transportation Research Part E, Logistics and Transportation Review*, *148*, 102246. 10.1016/j.tre.2021.102246

Ren, J., Liang, H., & Chan, F. T. (2017). Urban sewage sludge, sustainability, and transition for Eco-City: Multi-criteria sustainability assessment of technologies based on best-worst method. *Technological Forecasting and Social Change*, *116*, 29–39. 10.1016/j.techfore.2016.10.070

Rocco, C. M., Hernandez-Perdomo, E., & Mun, J. (2021). Assessing manufacturing flow lines under uncertainties in processing time: An application based on max-plus equations, multicriteria decisions, and global sensitivity analysis. *International Journal of Production Economics*, *234*, 108070. 10.1016/j.ijpe.2021.108070

Roh, S., Pettit, S., Harris, I., & Beresford, A. (2015). The pre-positioning of warehouses at regional and local levels for a humanitarian relief organisation. *International Journal of Production Economics*, *170*, 616–628. 10.1016/j.ijpe.2015.01.015

Roszkowska, E., & Wachowicz, T. (2015). Application of fuzzy TOPSIS to scoring the negotiation offers in ill-structured negotiation problems. *European Journal of Operational Research*, *242*(3), 920–932. 10.1016/j.ejor.2014.10.050

Safa, M., Shahi, A., Haas, C. T., & Hipel, K. W. (2014). Supplier selection process in an integrated construction materials management model. *Automation in Construction*, *48*, 64–73. 10.1016/j.autcon.2014.08.008

Sánchez-Lozano, J. M., García-Cascales, M. S., & Lamata, M. T. (2015). Evaluation of suitable locations for the installation of solar thermoelectric power plants. *Computers & Industrial Engineering*, *87*, 343–355. 10.1016/j.cie.2015.05.028

Sari, K., & Suslu, M. (2018). A modeling approach for evaluating green performance of a hotel supply chain. *Technological Forecasting and Social Change*, *137*, 53–60. 10.1016/j.techfore.2018.06.041

Seiti, H., & Hafezalkotob, A. (2019). Developing the R-TOPSIS methodology for risk-based preventive maintenance planning: A case study in rolling mill company. *Computers & Industrial Engineering*, *128*, 622–636. 10.1016/j.cie.2019.01.012

Shahsavar, A., Najafi, A. A., & Niaki, S. T. A. (2015). Three self-adaptive multi-objective evolutionary algorithms for a triple-objective project scheduling problem. *Computers & Industrial Engineering*, *87*, 4–15. 10.1016/j.cie.2015.04.027

Shanian, A., & Savadogo, O. (2006). TOPSIS multiple-criteria decision support analysis for material selection of metallic bipolar plates for polymer electrolyte fuel cell. *Journal of Power Sources*, *159*(2), 1095–1104. 10.1016/j.jpowsour.2005.12.092

Sheu, J.-B. (2008). A hybrid neuro-fuzzy analytical approach to mode choice of global logistics management. *European Journal of Operational Research*, *189*(3), 971–986. 10.1016/j.ejor.2006.06.082

Sheu, J.-B. (2010). Dynamic relief-demand management for emergency logistics operations under large-scale disasters. *Transportation Research Part E, Logistics and Transportation Review*, *46*(1), 1–17. 10.1016/j.tre.2009.07.005

Shi, K., & Asgari, A. (2022). Energy, exergy, and exergoeconomic analyses and optimization of a novel thermal and compressed air energy storage integrated with a dual-pressure organic Rankine cycle and ejector refrigeration cycle. *Journal of Energy Storage*, *47*, 103610. 10.1016/j.est.2021.103610

Shidpour, H., Shahrokhi, M., & Bernard, A. (2013). A multi-objective programming approach, integrated into the TOPSIS method, in order to optimize product design; in three-dimensional concurrent engineering. *Computers & Industrial Engineering*, *64*(4), 875–885. 10.1016/j.cie.2012.12.016

Shih, H.-S. (2008). Incremental analysis for MCDM with an application to group TOPSIS. *European Journal of Operational Research*, *186*(2), 720–734. 10.1016/j.ejor.2007.02.012

Shih, H.-S. (2022a). TOPSIS Applications. In *TOPSIS and its Extensions: A Distance-Based MCDM Approach* (pp. 201–215). Springer. 10.1007/978-3-031-09577-1_9

Shih, H.-S. (2022b). TOPSIS Basics. *TOPSIS and its Extensions: A Distance-Based MCDM Approach*, 17-31.

Shih, H.-S., & Olson, D. L. (2022). *TOPSIS and its extensions: A distance-based MCDM approach* (*Vol. 447*). Springer Nature. 10.1007/978-3-031-09577-1

Shyur, H.-J., & Shih, H.-S. (2006). A hybrid MCDM model for strategic vendor selection. *Mathematical and Computer Modelling*, *44*(7-8), 749–761. 10.1016/j.mcm.2005.04.018

Sianaki, O. A., Masoum, M. A., & Potdar, V. (2018). A decision support algorithm for assessing the engagement of a demand response program in the industrial sector of the smart grid. *Computers & Industrial Engineering*, *115*, 123–137. 10.1016/j.cie.2017.10.016

Siltori, P. F., Anholon, R., Rampasso, I. S., Quelhas, O. L., Santa-Eulalia, L. A., & Leal Filho, W. (2021). Industry 4.0 and corporate sustainability: An exploratory analysis of possible impacts in the Brazilian context. *Technological Forecasting and Social Change*, *167*, 120741. 10.1016/j.techfore.2021.120741

Singh, A. (2014). Supplier evaluation and demand allocation among suppliers in a supply chain. *Journal of Purchasing and Supply Management*, *20*(3), 167–176. 10.1016/j.pursup.2014.02.001

Singh, S., Misra, S. C., & Kumar, S. (2020). Identification and ranking of the risk factors involved in PLM implementation. *International Journal of Production Economics*, *222*, 107496. 10.1016/j.ijpe.2019.09.017

Siregar, I. (2019). Supplier selection by using analytical hierarchy process (ahp) and techniques for order preference methods with similarities to ideal solutions (topsis). *Journal of Physics: Conference Series*, *1339*(1), 012023. 10.1088/1742-6596/1339/1/012023

Sirisawat, P., & Kiatcharoenpol, T. (2018). Fuzzy AHP-TOPSIS approaches to prioritizing solutions for reverse logistics barriers. *Computers & Industrial Engineering*, *117*, 303–318. 10.1016/j.cie.2018.01.015

Sobhani, M. G., Imtiyaz, M. N., Azam, M. S., & Hossain, M. (2020). A framework for analyzing the competitiveness of unconventional modes of transportation in developing cities. *Transportation Research Part A, Policy and Practice*, *137*, 504–518. 10.1016/j.tra.2019.02.001

Sohaib, O., Naderpour, M., Hussain, W., & Martinez, L. (2019). Cloud computing model selection for e-commerce enterprises using a new 2-tuple fuzzy linguistic decision-making method. *Computers & Industrial Engineering*, *132*, 47–58. 10.1016/j.cie.2019.04.020

Sohani, A., Dehnavi, A., Sayyaadi, H., Hoseinzadeh, S., Goodarzi, E., Garcia, D. A., & Groppi, D. (2022). The real-time dynamic multi-objective optimization of a building integrated photovoltaic thermal (BIPV/T) system enhanced by phase change materials. *Journal of Energy Storage*, *46*, 103777. 10.1016/j.est.2021.103777

Sureeyatanapas, P., Sriwattananusart, K., Niyamosoth, T., Sessomboon, W., & Arunyanart, S. (2018). Supplier selection towards uncertain and unavailable information: An extension of TOPSIS method. *Operations Research Perspectives*, *5*, 69–79. 10.1016/j.orp.2018.01.005

Taleizadeh, A. A., Niaki, S. T. A., & Aryanezhad, M.-B. (2009). A hybrid method of Pareto, TOPSIS and genetic algorithm to optimize multi-product multi-constraint inventory control systems with random fuzzy replenishments. *Mathematical and Computer Modelling*, *49*(5-6), 1044–1057. 10.1016/j.mcm.2008.10.013

Tanrıverdi, G., & Lezki, Ş. (2021). Istanbul Airport (IGA) and quest of best competitive strategy for air cargo carriers in new competition environment: A fuzzy multi-criteria approach. *Journal of Air Transport Management*, *95*, 102088. 10.1016/j.jairtraman.2021.102088

Tavana, M., Khosrojerdi, G., Mina, H., & Rahman, A. (2020). A new dynamic two-stage mathematical programming model under uncertainty for project evaluation and selection. *Computers & Industrial Engineering*, *149*, 106795. 10.1016/j.cie.2020.106795

Tavana, M., Nasr, A. K., Mina, H., & Michnik, J. (2021). A private sustainable partner selection model for green public-private partnerships and regional economic development. *Socio-Economic Planning Sciences*, ●●●, 101189.

Tavana, M., Zarook, Y., & Santos-Arteaga, F. J. (2015). An integrated three-stage maintenance scheduling model for unrelated parallel machines with aging effect and multi-maintenance activities. *Computers & Industrial Engineering*, *83*, 226–236. 10.1016/j.cie.2015.02.012

Thong, N. T., Dat, L. Q., Hoa, N. D., Ali, M., & Smarandache, F. (2019). Dynamic interval valued neutrosophic set: Modeling decision making in dynamic environments. *Computers in Industry*, *108*, 45–52. 10.1016/j.compind.2019.02.009

Tong, L.-I., Wang, C.-H., Chen, C.-C., & Chen, C.-T. (2004). Dynamic multiple responses by ideal solution analysis. *European Journal of Operational Research*, *156*(2), 433–444. 10.1016/S0377-2217(03)00017-1

Tseng, M.-L., Wu, K.-J., Hu, J., & Wang, C.-H. (2018). Decision-making model for sustainable supply chain finance under uncertainties. *International Journal of Production Economics*, *205*, 30–36. 10.1016/j.ijpe.2018.08.024

Turan, H. H., Jalalvand, F., Kahagalage, S., & El Sawah, S. (2021). Integrating decision maker preferences to a risk-averse multi-objective simulation-based optimization for a military workforce planning, asset management and fleet management problem. *Computers & Industrial Engineering*, *162*, 107752. 10.1016/j.cie.2021.107752

Unutmaz Durmuşoğlu, Z. D., & Durmuşoğlu, A. (2021). A TOPSIS model for understanding the authors choice of journal selection. *Scientometrics*, *126*(1), 521–543. 10.1007/s11192-020-03770-5

Uygun, Ö., & Dede, A. (2016). Performance evaluation of green supply chain management using integrated fuzzy multi-criteria decision making techniques. *Computers & Industrial Engineering*, *102*, 502–511. 10.1016/j.cie.2016.02.020

Uygun, Ö., Kahveci, T. C., Taşkın, H., & Piriştine, B. (2015). Readiness assessment model for institutionalization of SMEs using fuzzy hybrid MCDM techniques. *Computers & Industrial Engineering*, *88*, 217–228. 10.1016/j.cie.2015.07.008

Validi, S., Bhattacharya, A., & Byrne, P. (2014). A case analysis of a sustainable food supply chain distribution system—A multi-objective approach. *International Journal of Production Economics*, *152*, 71–87. 10.1016/j.ijpe.2014.02.003

Vincent, F. Y., & Hu, K.-J. (2010). An integrated fuzzy multi-criteria approach for the performance evaluation of multiple manufacturing plants. *Computers & Industrial Engineering*, *58*(2), 269–277. 10.1016/j.cie.2009.10.005

Walczak, D., & Rutkowska, A. (2017). Project rankings for participatory budget based on the fuzzy TOPSIS method. *European Journal of Operational Research*, *260*(2), 706–714. 10.1016/j.ejor.2016.12.044

Wan, S.-P., Li, S.-Q., & Dong, J.-Y. (2018). A three-phase method for Pythagorean fuzzy multi-attribute group decision making and application to haze management. *Computers & Industrial Engineering*, *123*, 348–363. 10.1016/j.cie.2018.07.005

Wan, S.-P., Wang, F., Lin, L.-L., & Dong, J.-Y. (2016). Some new generalized aggregation operators for triangular intuitionistic fuzzy numbers and application to multi-attribute group decision making. *Computers & Industrial Engineering*, *93*, 286–301. 10.1016/j.cie.2015.12.027

Wang, C.-H., & Shih, C.-W. (2013). Integrating conjoint analysis with quality function deployment to carry out customer-driven concept development for ultrabooks. *Computer Standards & Interfaces*, *36*(1), 89–96. 10.1016/j.csi.2013.07.010

Wang, G., & Duan, Y. (2018). TOPSIS approach for multi-attribute decision making problems based on n-intuitionistic polygonal fuzzy sets description. *Computers & Industrial Engineering*, *124*, 573–581. 10.1016/j.cie.2018.07.038

Wang, L., Wang, Z., & Ma, Y. (2021). Does environmental regulation promote the high-quality development of manufacturing? A quasi-natural experiment based on China's carbon emission trading pilot scheme. *Socio-Economic Planning Sciences*, ●●●, 101216.

Wang, T., Liu, J., Li, J., & Niu, C. (2016). An integrating OWA–TOPSIS framework in intuitionistic fuzzy settings for multiple attribute decision making. *Computers & Industrial Engineering*, *98*, 185–194. 10.1016/j.cie.2016.05.029

Wang, X. (2015). A comprehensive decision making model for the evaluation of green operations initiatives. *Technological Forecasting and Social Change*, *95*, 191–207. 10.1016/j.techfore.2015.02.004

Wang, X., Chan, H. K., & Li, D. (2015). A case study of an integrated fuzzy methodology for green product development. *European Journal of Operational Research*, *241*(1), 212–223. 10.1016/j.ejor.2014.08.007

Wang, Y.-M., Luo, Y., & Hua, Z.-S. (2007). A note on group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment. *Mathematical and Computer Modelling*, *46*(9-10), 1256–1264. 10.1016/j.mcm.2007.01.003

Wanke, P., Barros, C. P., & Chen, Z. (2015). An analysis of Asian airlines efficiency with two-stage TOPSIS and MCMC generalized linear mixed models. *International Journal of Production Economics*, *169*, 110–126. 10.1016/j.ijpe.2015.07.028

Wei, H., & Lee, P. T.-W. (2021). Designing a coordinated horizontal alliance system for China's inland ports with China railway express platforms along the Silk Road Economic Belt. *Transportation Research Part E, Logistics and Transportation Review*, *147*, 102238. 10.1016/j.tre.2021.102238

Wu, C.-S., Lin, C.-T., & Lee, C. (2010). Optimal marketing strategy: A decision-making with ANP and TOPSIS. *International Journal of Production Economics*, *127*(1), 190–196. 10.1016/j.ijpe.2010.05.013

Xu, Z. (2013). Group decision making model and approach based on interval preference orderings. *Computers & Industrial Engineering*, *64*(3), 797–803. 10.1016/j.cie.2012.12.013

Yadavalli, V. S., Darbari, J. D., Bhayana, N., Jha, P., & Agarwal, V. (2019). An integrated optimization model for selection of sustainable suppliers based on customers' expectations. *Operations Research Perspectives*, *6*, 100113. 10.1016/j.orp.2019.100113

Yang, T., Chen, M.-C., & Hung, C.-C. (2007). Multiple attribute decision-making methods for the dynamic operator allocation problem. *Mathematics and Computers in Simulation*, *73*(5), 285–299. 10.1016/j.matcom.2006.04.002

Yang, T., & Chou, P. (2005). Solving a multiresponse simulation-optimization problem with discrete variables using a multiple-attribute decision-making method. *Mathematics and Computers in Simulation*, *68*(1), 9–21. 10.1016/j.matcom.2004.09.004

Yang, T., Wen, Y.-F., & Wang, F.-F. (2011). Evaluation of robustness of supply chain information-sharing strategies using a hybrid Taguchi and multiple criteria decision-making method. *International Journal of Production Economics*, *134*(2), 458–466. 10.1016/j.ijpe.2009.11.018

Yeh, C.-H., & Chang, Y.-H. (2009). Modeling subjective evaluation for fuzzy group multicriteria decision making. *European Journal of Operational Research*, *194*(2), 464–473. 10.1016/j.ejor.2007.12.029

Yoon, K., & Hwang, C. L. (1981). *TOPSIS (technique for order preference by similarity to ideal solution)–a multiple attribute decision making, w: Multiple attribute decision making–methods and applications, a state-of-the-at survey*. Springer Verlag.

Yuan, J., & Luo, X. (2019). Approach for multi-attribute decision making based on novel intuitionistic fuzzy entropy and evidential reasoning. *Computers & Industrial Engineering*, *135*, 643–654. 10.1016/j.cie.2019.06.031

Yue, C. (2016). A geometric approach for ranking interval-valued intuitionistic fuzzy numbers with an application to group decision-making. *Computers & Industrial Engineering*, *102*, 233–245. 10.1016/j.cie.2016.10.027

Yue, Z., & Jia, Y. (2015). A group decision making model with hybrid intuitionistic fuzzy information. *Computers & Industrial Engineering*, *87*, 202–212. 10.1016/j.cie.2015.05.016

Zabihi, S., Kahag, M. R., Maghsoudlou, H., & Afshar-Nadjafi, B. (2019). Multi-objective teaching-learning-based meta-heuristic algorithms to solve multi-skilled project scheduling problem. *Computers & Industrial Engineering*, *136*, 195–211. 10.1016/j.cie.2019.07.032

Zaidan, A., Zaidan, B., Hussain, M., Haiqi, A., Kiah, M. M., & Abdulnabi, M. (2015). Multi-criteria analysis for OS-EMR software selection problem: A comparative study. *Decision Support Systems*, *78*, 15–27. 10.1016/j.dss.2015.07.002

Zamani-Sabzi, H., King, J. P., Gard, C. C., & Abudu, S. (2016). Statistical and analytical comparison of multi-criteria decision-making techniques under fuzzy environment. *Operations Research Perspectives*, *3*, 92–117. 10.1016/j.orp.2016.11.001

Zanakis, S. H., Solomon, A., Wishart, N., & Dublish, S. (1998). Multi-attribute decision making: A simulation comparison of select methods. *European Journal of Operational Research*, *107*(3), 507–529. 10.1016/S0377-2217(97)00147-1

Zandi, F., & Tavana, M. (2011). A fuzzy group quality function deployment model for e-CRM framework assessment in agile manufacturing. *Computers & Industrial Engineering*, *61*(1), 1–19. 10.1016/j.cie.2011.02.004

Zhan, J., Sun, B., & Zhang, X. (2020). PF-TOPSIS method based on CPFRS models: An application to unconventional emergency events. *Computers & Industrial Engineering*, *139*, 106192. 10.1016/j.cie.2019.106192

Zhang, B., Pan, Q., Gao, L., Li, X.-y., Meng, L., & Peng, K. (2019). A multiobjective evolutionary algorithm based on decomposition for hybrid flowshop green scheduling problem. *Computers & Industrial Engineering*, *136*, 325–344. 10.1016/j.cie.2019.07.036

Zhang, H., Xie, J., Lu, W., Zhang, Z., & Fu, X. (2019). Novel ranking method for intuitionistic fuzzy values based on information fusion. *Computers & Industrial Engineering*, *133*, 139–152. 10.1016/j.cie.2019.05.006

Zhang, L., Wang, T., Li, H., Huang, B., & Zhou, X. (2019). Agent evaluation based on multi-source heterogeneous information table using TOPSIS. *Advanced Engineering Informatics*, *42*, 100971. 10.1016/j.aei.2019.100971

Zhang, X., & Su, J. (2019). A combined fuzzy DEMATEL and TOPSIS approach for estimating participants in knowledge-intensive crowdsourcing. *Computers & Industrial Engineering*, *137*, 106085. 10.1016/j.cie.2019.106085

Zhang, Z., & Pan, W. (2021). Multi-criteria decision analysis for tower crane layout planning in high-rise modular integrated construction. *Automation in Construction*, *127*, 103709. 10.1016/j.autcon.2021.103709

Zhao, J., & Ke, G. Y. (2017). Incorporating inventory risks in location-routing models for explosive waste management. *International Journal of Production Economics*, *193*, 123–136. 10.1016/j.ijpe.2017.07.001

Zhao, S., Liu, W., Zhu, M., Ma, Y., & Li, Z. (2021). A priority-based multi-objective framework for water resources diversion and allocation in the middle route of the South-to-North Water Diversion Project. *Socio-Economic Planning Sciences*, *78*, 101085. 10.1016/j.seps.2021.101085

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